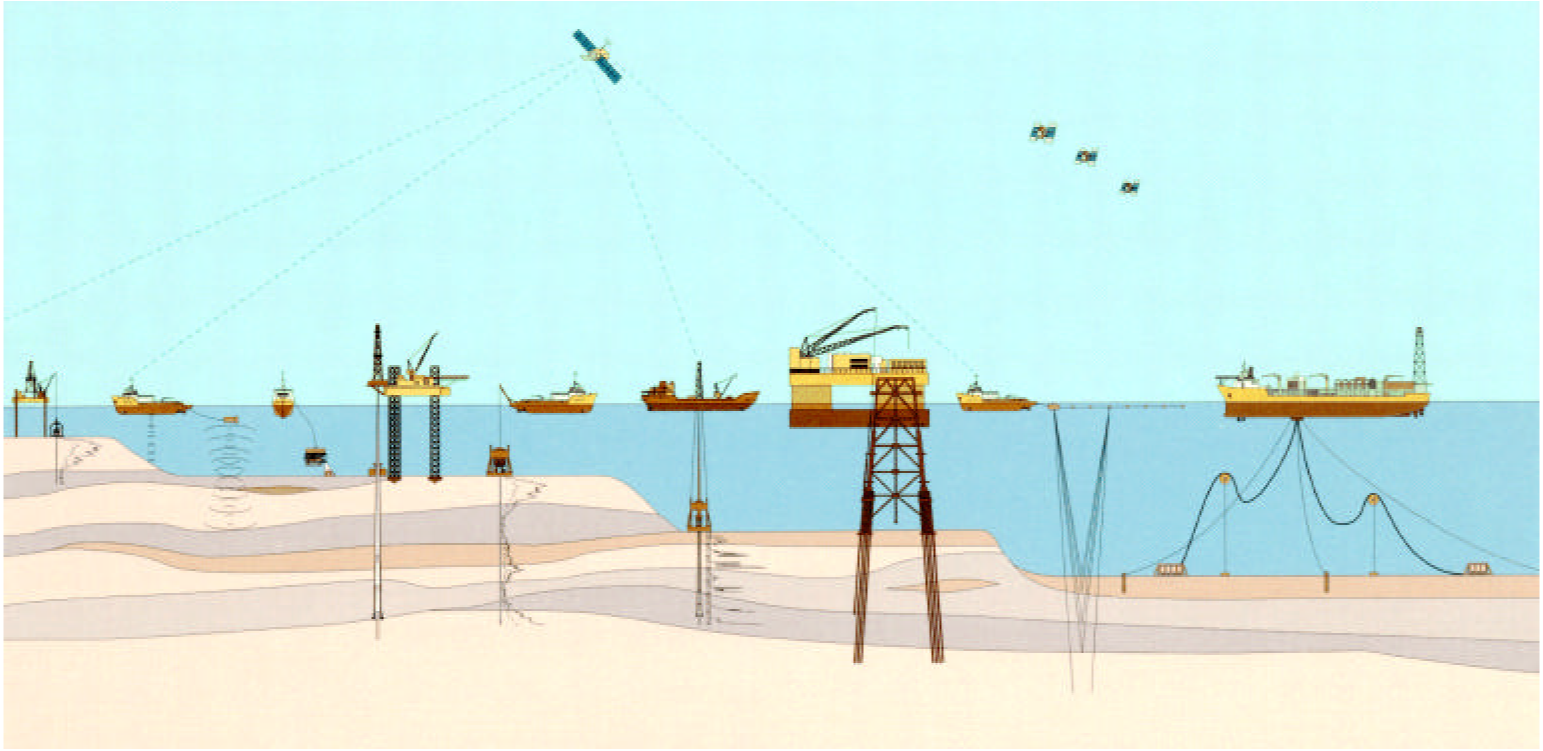
INFORMATION HANDOUT
STRUCTURES CHAPTER

FOR THE
PILE INSTALLATION DEMONSTRATION PROJECT
SAN FRANCISCO-OAKLAND BAY BRIDGE
EAST SPAN SEISMIC SAFETY PROJECT

Prepared for:
CALIFORNIA DEPARTMENT OF TRANSPORTATION
CONTRACT EA NO. 04-012084

June 1999



Earth Mechanics

Fugro - Earth Mechanics
A JOINT VENTURE

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TRANSMITTAL

July 6, 1999
Project No. 98-42-0061

California Department of Transportation
Division of Structures, MS9
1801 30th Street
Sacramento, California 95816

Attention: Ms. Sharon Amlin Naramore

Subject: Information Handout, Structures Chapter for the Pile Installation Demonstration Project, San Francisco-Oakland Bay Bridge East Span Seismic Safety Project

We are transmitting 18 bound and 2 unbound copies of the information outlined below to be included in the Contractor Information Handout for the Pile Installation Demonstration Project (PIDP):

1. Project Memorandum, *Overview of Site Conditions for the SFOBB East Span Seismic Safety Project and Pile Installation Demonstration Project*, *Caltrans Contract EA No. 04-012084*, dated June 25, 1999
2. Project Memorandum, *Factual Soils Data, Borings 98-49 and 98-82, PID Project, Caltrans Contract EA No. 04-01208,* dated July 12, 1999
3. Project Memorandum, *Preliminary Pile Drivability Evaluation, SFOBB East Span Seismic Safety Project*, dated May 13, 1998
4. Large Offshore Hammer Inventory and List of Hammer Manufacturers

Other copies are being sent to:

Caltrans
Attn: ***Mr. Mark Willian*** *.................................. 2 copies*
Mr. Reid Buell *....................................... 3 copies*
Engineering Service Center
Office of Structural Foundations
5900 Folsom Boulevard
Post Office Box 19128
Sacramento, California 95819-0128

Caltrans, District 4
Attn: ***Dr. Brian Maroney****........................... 1 copy*
111 Grand Avenue
Post Office Box 23660
Mail Station 12
Oakland, California 94623-0660

Please call if you have any questions.

Sincerely,

FUGRO WEST, INC.
(on behalf of Fugro-Earth Mechanics, a Joint Venture)

Anthony R. Dover, P.E.
Vice President

☒ Overnight a.m.

INFORMATION HANDOUT
STRUCTURES CHAPTER
FOR THE
PILE INSTALLATION DEMONSTRATION PROJECT
SAN FRANCISCO-OAKLAND BAY BRIDGE
EAST SPAN SEISMIC SAFETY PROJECT

CONTENTS

[1] Additional drivability information is provided in *Draft Axial Pile Design and Drivability, Main Span East Pier and Skyway Structures, San Francisco-Oakland Bay Bridge East Span Seismic Safety Project*, prepared by Fugro-Earth Mechanics for California Department of Transportation, May 1999.

PROJECT MEMORANDUM, OVERVIEW OF SITE CONDITIONS FOR THE SFOBB EAST SPAN SEISMIC SAFETY PROJECT AND PILE INSTALLATION DEMONSTRATION PROJECT, CALTRANS CONTRACT EA NO. 04-012084, DATED JUNE 25, 1999

FUGRO WEST, INC.

5855 Olivas Park Drive
Ventura CA 93003-7672
Tel: (805) 650-7000
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June 25, 1999
Fugro Project No. 98-42-0061

PROJECT MEMORANDUM

To: Mr. Mark Willian, Caltrans (2 copies)
Mr. Reid Buell, Caltrans (3 copies)
Dr. Brian Maroney, Caltrans (1 copy)
Ms. Sharon Amlin Naramore, Caltrans (1 copy)

From: Messrs. Roger Howard and Tony Dover, P.E., Fugro

Subject: **Overview of Site Conditions for the SFOBB East Span Seismic Safety Project and Pile Installation Demonstration Project (PIDP), Caltrans Contract EA No. 04-012084**

The following discussion summarizes the subsurface stratigraphy and subsurface conditions underlying the Main Span East Pier, Skyway of the N6 alignment and the Pile Installation Demonstration Project (PIDP) area. The following discussion is limited to the conditions underlying the approximately 70-meter-wide N6 alignment corridor and the PIDP locations. The discussion also is limited to the stratigraphic section within the anticipated depth penetrated by and immediately underlying the bridge pile foundations and PID pile locations (i.e., this discussion is limited to the sediment section above about El. -110 meters).

SAN FRANCISCO BAY BATHYMETRY

As shown on Plate 1, the bay bottom along the N6 alignment generally slopes from less than 0.15 percent to about 2 percent from east to west to within about 300 meters offshore from Yerba Buena Island. Offshore from Yerba Buena Island, the surface slopes more steeply to the east. The lowest elevation in the vicinity of the alignment is about El. -30 meters (re: MSL datum) in the deep scour depression offshore from the eastern tip of Yerba Buena Island.

A north-south-trending channel is located to the east of Yerba Buena Island. Along the channel axis, the nominal elevation of the channel base is El. -15 meters. Between the existing Bridge Piers E2 and E3, however, the channel reaches a depth of El. -30 meters. This scour hole is about 700 by 300 meters and is elongated in a north-southwest direction. It is more than 15 meters deep relative to its outlet to the southwest. The east- and west-facing slopes of the depression, which underlie the area between the Main Span pylon and East Pier, are as steep as about 10 to 30 percent while the north- and south-facing slopes are more typically about 3 to 4 percent.

Local scour holes also are adjacent to most of the piers on the existing bridge. To the west of existing Bridge Pier E12, the scour holes are to the south of the piers. The scour depressions are more than 4 meters deep at Bridge Piers E3 and E4, and about 1 to 3 meters deep at the other piers. There also are 1- to 2-meter-deep scour depressions to the east of existing Bridge Piers E13 through E16.

In the vicinity of the proposed PIDP area, the bay floor slopes down to the west. The bathymetric features around the proposed PIDP location are described below:

- A north-south-trending, approximately 5-meter-high slope is present below the primary PIDP location and the eastern half of Skyway Frame 1. In this area, the bay bottom deepens from about El. -7 to -12 meters over a horizontal distance of about 300 meters. The bay bottom is locally as steep as about 2 percent in this area of steeper bay bottom. In the immediate vicinity of the primary PIDP pile test location the mudline is approximately between El. -9 and -9.5 meters.
- The Pile No. 3 test location and the alternate Pile No. 3 test location are located on the high side of the above mentioned 5-meter-high slope. The mudline elevations at the Pile No. 3 test location and the alternate Pile No. 3 test location are approximately El. -5.5 and -7.5 meters, respectively.
- There is an apparent localized depression, possibly due to scour from the adjacent bridge pier, of about 1 to 2 meters near the location of the Pile No. 3 test location.

A variety of cultural features were observed on the side scan sonar data in the survey area. These features include several utility cables and pipelines as well as: a) debris; b) scour depressions; c) changes in sediment density; d) small linear anomalies from anchor chains, buoys, pipelines, and cables; f) bedrock outcrops; g) bridge piers, dolphins, signs, platforms, and other obstructions with a positive relief; and h) unidentifiable features of unknown origin. The features were shown on a 1:2000-scale map in the Preliminary Marine Geophysical Survey Summary Report[1].

GEOLOGIC FEATURES AND SUBSURFACE STRATIGRAPHY

Principal Features and Formations

The geologic structure underlying the N6 alignment and the PIDP area includes the following general features:

[1] Fugro-Earth Mechanics (Fugro-EM) (1998), *Preliminary Marine Geophysical Survey Summary, San Francisco-Oakland Bay Bridge East Span Replacement Project*, Map 1, Sheets 1 and 2, FWI Job No. 98-42-0018, prepared for California Department of Transportation, March 20.

- Easterly-sloping bedrock of the Franciscan Formation
- A westerly-thinning sequence of Holocene- and Pleistocene-age marine and alluvial sediments
- Extensive channeling within the Holocene- and Pleistocene-age sediments

The geologic formations that underlie the N6 alignment (or portions of the alignment) and the PIDP area are listed in descending sequence:

- Young Bay Mud (YBM)
- Merritt-Posey-San Antonio Formations (sometimes simplified as the Merritt Sand) (MPSA)
- Old (Yerba Buena) Bay Mud (OBM)
- Upper Alameda (primarily marine) Sediments (UAM)
- Lower Alameda (primarily alluvial sand) Sediments (LAA)
- Franciscan Formation (FF)

Descriptions of the sediments in each of those units are provided subsequently.

Subsurface Cross Sections

A series of four cross sections along the centerline of N6 alignment show the soil lithologies encountered in the borings, measured undrained strength data from the borings, and the interpreted stratigraphic contacts, as imaged on the marine geophysical records. The locations of the cross sections are shown on Plates 2a and 2b. A key to the lithographic symbols used on the cross sections is provided on Plate 3. The cross sections along the N6 alignment are presented on Plates 4 through 7.

In addition, two cross sections are shown through the PIDP test locations. These include an east-west cross section through the PID location (Plate 8), and a North-South cross section through the primary PID location shown on (Plate 9). In addition to the undrained shear strength data, the cross sections through the PIDP test locations include CPT tip resistance data.

DESCRIPTION OF GEOLOGIC FEATURES

Easterly-Sloping Bedrock of the Franciscan Formation

Bedrock Surface Contours. The eastern San Francisco Bay is underlain by the Franciscan Formation bedrock, which slopes to the east from Yerba Buena Island. A prominent bedrock high or nose extends to the northeast of Yerba Buena Island. Offshore, the bedrock slopes down (at an inclination of between about 2.5 horizontal to 1 vertical [2.5H:1V] to 3.5H:1V [approximately 15 to 22 degrees]) to the north, east, and southeast from the edge of the island out to about El. -70 meters on the north and El. -95 meters on the east and southeast.

Along the N6 alignment, the bedrock slope flattens about 70 meters to the west of the Main Span East Pier. From that point, the bedrock surface continues to slope to the east, but at a flatter average slope of about 1.5 to 2 percent (approximately 0.8 to 1.2 degrees), and reaches about El. -135 meters near the tip of the Oakland Mole.

At the primary PIDP test location, the bedrock is expected at about El. -100 to -105 meters.

Bedrock Lithology. The bedrock beneath the N6 alignment and the PIDP location consists primarily of thickly bedded to massive sandstone (graywacke) with thinly interbedded siltstone and claystone. The upper approximately 6 to 9 meters of bedrock is typically moderately weathered. The weathered zone is underlain by a relatively thin, 1.5- to 3-meter-thick layer of slightly weathered rock, with up to 12 mm of light brown moderately weathered rock on each side of the fractures and joints.

Below the weathered zone, the fresh sandstone is typically moderately to slightly fractured, with zones of intensely fractured sandstone up to about 1.5 to 1.8 meters thick in several borings.

Holocene- and Pleistocene-Age Marine and Alluvial Sediments

Sediment Structure. A westerly-thinning sequence of Holocene- and Pleistocene-age marine and alluvial sediments unconformably overlay the Franciscan Formation bedrock below the PID location and along the N6 alignment. In general, the marine sediments (deposited during sea level high stands) are primarily clays and silts. The alluvial sediments (deposited during sea level low stands) are more commonly sands. In some depth zones, sequences that are composed of primarily fine-grained marine clays contain interbedded layers of sand. In addition, the primarily granular alluvial sequences typically contain significant quantities of fine-grained layers.

Except where eroded and then backfilled by past sequences of channeling, the inclination of the bedding of the marine and alluvial sediments is slight and, for practical purposes, the bedding can be considered to be near horizontal. The Holocene- and Pleistocene-age marine and alluvial sediments, however, are frequently interfingered and interlayered. Thus, although the stratigraphic sequence generally can be extrapolated between borings (and geophysical tracklines), the lithologic and geotechnical properties of the soils can vary significantly over limited horizontal distances.

Channeling

The SFOBB East Span project area contains a series of nested, shallow, buried paleochannels. These channels include: a) east-west-trending channeling to the north of the existing SFOBB alignment (consistent with the channeling mapped by Trask and Rolston

[1951]), b) tributary south-to-north channels associated with the east-west channeling, and c) north-south-oriented channeling in the western third of the survey area. In general, the marine clays are thicker and the alluvial sands are thinner (or absent) within the buried paleochannels.

As shown in Plate 10, the N6 Skyway alignment generally overlies the meandering, southern flank of the east-west-trending nested set of paleochannels, and crosses several north-south tributaries of that channel. Because of the channeling, variations of the thickness of surficial very soft to soft clay and the presence or absence of near-surface sand layers are inevitable beneath the Skyway alignment. This juxtaposition will produce significant subsurface variation across and along the N6 alignment down to at least El. -24 meters. Those variations may occur across the width of an individual pier, between adjacent piers, and/or between adjacent Skyway frames.

The primary PID test location is outside any of the paleochannels while the Pile No. 3 Test Location and Alternative Test Location straddle a smaller north-south trending paleochannel, which passes to the west of Pier E7.

FORMATION DESCRIPTION

The geologic formations (as defined by Caltrans, 1997) that underlie the N6 alignment and the PIDP area (or portions of the alignment and area) include (in descending sequence):

- Young Bay Mud (YBM)
- Merritt-Posey-San Antonio Formations (sometimes simplified as the Merritt Sand) (MPSA)
- Old (Yerba Buena) Bay Mud (OBM)
- Upper Alameda (primarily marine) Sediments (UAM)
- Lower Alameda (primarily alluvial sand) Sediments (LAA)
- Franciscan Formation (FF)

While the formation designations are useful, we have chosen to also describe the subsurface conditions primarily in terms of undrained shear strength (of cohesive soils) and relative density or measured cone tip resistance (of granular soils). That choice was made based on the extensive test data from the 1998 Fugro borings and the direct applicability of the test data to foundation design.

The typical soil designations for the formations are as follows:

Formation Designation	Typical Soil Designation
Young Bay Mud	Very Soft to Soft or Soft to Firm Clay
Merritt-Posey-San Antonio Formations (also referred to as Merritt Sand)	Dense to Very Dense Sand with Stiff to Very Stiff Clay Layers

Formation Designation	Typical Soil Designation
Old Bay Mud and Upper Alameda Sediments	Very Stiff to Hard Clay
Lower Alameda Sediments	Dense to Very Dense Sand (or Very Dense Sand) and Hard Clay

The general relative relationships of these soil strata and formations are illustrated on cross sections. The following paragraphs provide an overview of each formation.

Young Bay Mud (YBM)

The Young Bay Mud is marine clay that has been deposited since the end of the last sea level low stand (approximately 11,000 years ago). The YBM occurs as a blanket of sediments that cover the majority of the bay bottom between Yerba Buena Island and the Oakland Mole and as infill in the recent paleochannels.

The Young Bay Mud typically is composed of fat clay. The YBM within the paleochannel is very soft to firm and its undrained shear strength increases with depth. The YBM paleochannel fill includes sand layers and/or seams within several depth intervals. The surface blanket of YBM is typically soft outside of the paleochannels. In the primary PIDP location the YBM is between about 4.5 and 6.1 meters thick, and ranges from between 10 and 20 meters thick for the Pile No. 3 test location and the Pile No. 3 alternate test location.

The Young Bay Mud provides only a relatively small percentage of the axial skin friction capacity of the piles or resistance to pile driving.

Merritt-Posey-San Antonio Formations (MPSA)

Beneath the Young Bay Mud, a layered sequence of sands and clays is present over portions of the eastern San Francisco Bay. The Merritt-Posey-San Antonio sequence includes dense to very dense sand with layers of stiff to very stiff sandy clay and clay. The geophysical reflections in the MPSA sequence are generally discontinuous and suggest that individual layers are often of limited lateral extent. Borings along the existing and proposed N6 bridge alignments suggest that the MPSA sequence generally is no more than 5 to 8 meters thick.

The MPSA is approximately 7.0 to 8.5 meters thick at the primary PID test location and thin to non-existent near the Pile No. 3 locations due to the proximity of a north-south trending paleochannel.

Old Bay Mud/Upper Alameda (Primarily Marine) Sediments (OBM/UAM)

The Old Bay Mud and Upper Alameda Sediments both consist primarily of very stiff to hard fat clay. Because the composition and geotechnical properties of the two units are similar and the definition of the interface between the two formations is tenuous, we have chosen to discuss and map the two formations as one combined sequence of sediments. Except where eroded by channeling, the top of the sequence typically is present from about El. -17 to -25 meters. Borings show that the combined typical 60-meter thickness of the two formations typically includes multiple crust layers with locally higher strength.

The majority of the axial pile capacity due to skin friction is derived in the Old Bay Mud and Upper Alameda Marine sediments. The marine clays that comprise the OBM and UAM sequences are generally very stiff to hard fat clays with shear strengths increasing from approximately 125 to 175 kilopascals (kPa) at the top of the sequence to about 150 to 250 kPa at the base of the sequence. The sequence also includes numerous crust layers where the undrained shear strengths are at least 25 to 50 kPa higher than the adjacent layers.

Although composed primarily of clay, the sequence includes some sand layers that tend to become more prevalent below about El. -65 meters. In the PID test locations sand layers are present within the OBM/UAM sequence around El. -57 meters. In addition a 6-meter layer of sand is present below approximately El. -68 meters in the primary PID test location.

In addition to the sand layers present in the OBM/UAM throughout the SFOBB project area there is a thick layer of very dense, fine to medium sand at about El. -70 meters located in the western third of the SFOBB project area. This sand layer has been defined as the Upper Alameda Marine paleochannel sand. The UAM paleochannel sand appears to infill a north-south-oriented paleochannel that is incised into the top of the UAM in the western one-third of the N6 alignment. On the west, the UAM paleochannel sands appear to overlap onto the eastward dipping Franciscan Formation. To the east, the UAM paleochannel sands extend to about the location of Skyway Frame 1, Pier 3. At the location of the Main Span East Pier, the UAM paleochannel sands are about 15 meters thick, and extend down to the top of the underlying Lower Alameda Alluvium. The UAM paleochannel sand does not extend to the PIDP test location areas.

Lower Alameda (Primarily Alluvial Sand) Sediments (LAA)

The sediments below about El. -80 to -85 meters are interpreted to be the primarily granular Lower Alameda (LAA) Sediments. The LAA includes a 3 to 10 meter thick cap layer of very stiff to hard lean clay (LAA-clay cap) underlain by a sequence of primarily very dense granular alluvial sediments (LAA-sands). The LAA-sands consist of a wide range of granular sediments that include very dense poorly graded silty fine sand and fine sand with silt, very dense, well-graded fine to coarse sand (or clayey fine to coarse sand) with gravel and poorly to widely graded gravel with sand and silt.

The borings show that the primarily alluvial LAA sediments also include an appreciable quantity of clay layers. Interbedded within the LAA-sands are layers of hard lean and fat clay (LAA-clay interbeds). The representative undrained shear strength of the LAA-clay cap is about 250 kPa. In contrast, the representative undrained shear strength of the LAA-clay interbeds is more typically about 350 to 400 kPa.

We anticipate that the Skyway pile foundations will consist of piles driven to tip at about one to two pile diameters into the first, relatively thick and continuous dense sand layer that is commonly present at or near the surface of the Lower Alameda Alluvial Formation.

At the primary PIDP test pile location the LAA-clay cap is expected at about El. -84 to El. -88 meters with the top of the LAA-sand approximately 2 to 4 meters below the top of the LAA-clay cap.

Attachments: Plate 1 - Bathymetry and Marine Explorations
Plates 2a,b - Cross Section Location Map
Plate 3 - Key to Cross Sections
Plate 4 - Subsurface Cross Section A1-A1' With Undrained Shear Strength
Plate 5 - Subsurface Cross Section A2-A2' With Undrained Shear Strength
Plate 6 - Subsurface Cross Section A3-A3' With Undrained Shear Strength
Plate 7 - Subsurface Cross Section A4-A4' With Undrained Shear Strength
Plate 8 - Subsurface Cross Section PID1-PID1' With Undrained Shear Strength
Plate 9 - Subsurface Cross Section PID2-PID2' With Undrained Shear Strength
Plate 10 - Young Bay Mud Paleochannel

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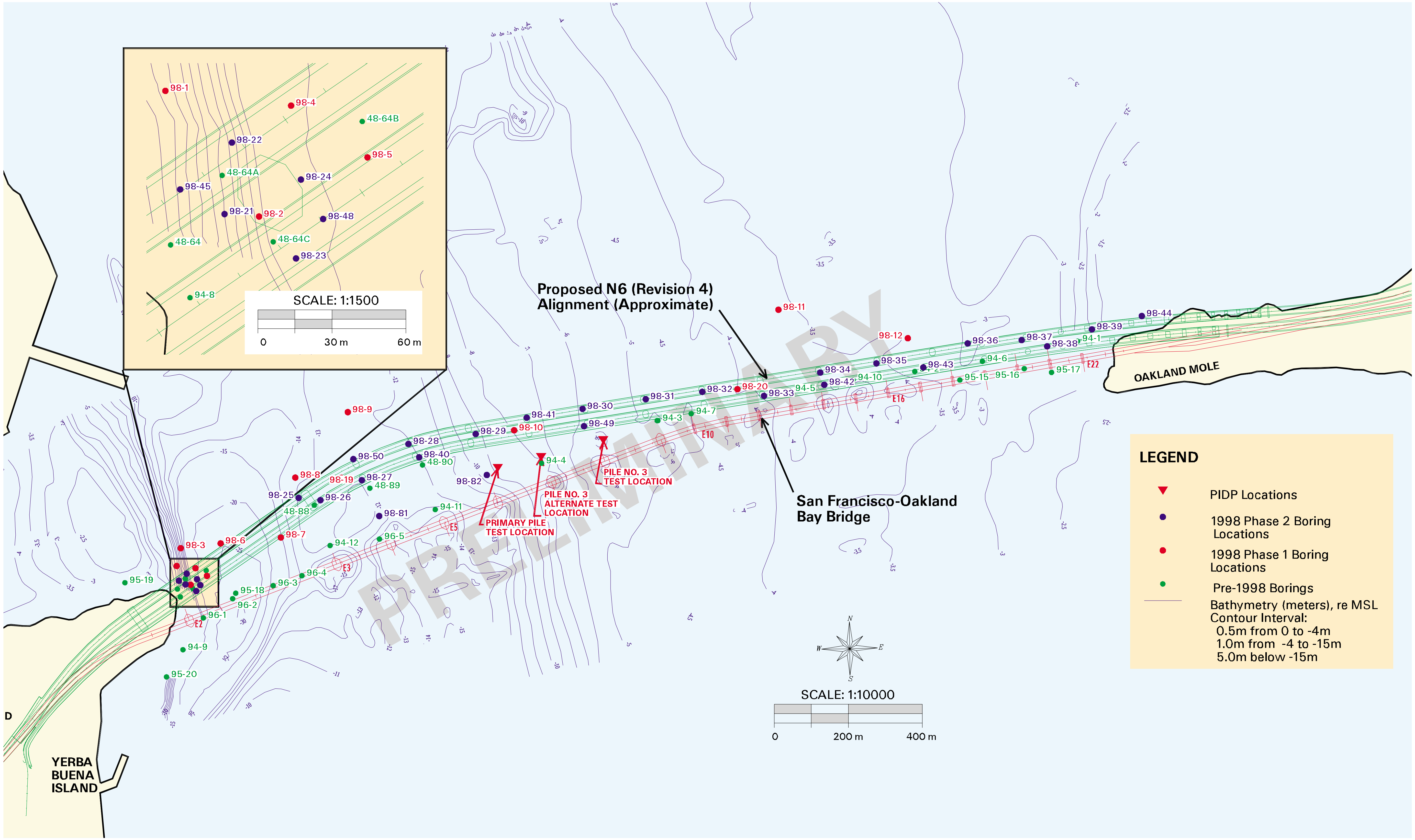

BATHYMETRY AND MARINE EXPLORATIONS
SFOBB East Span Seismic Safety Project

PLATE 1

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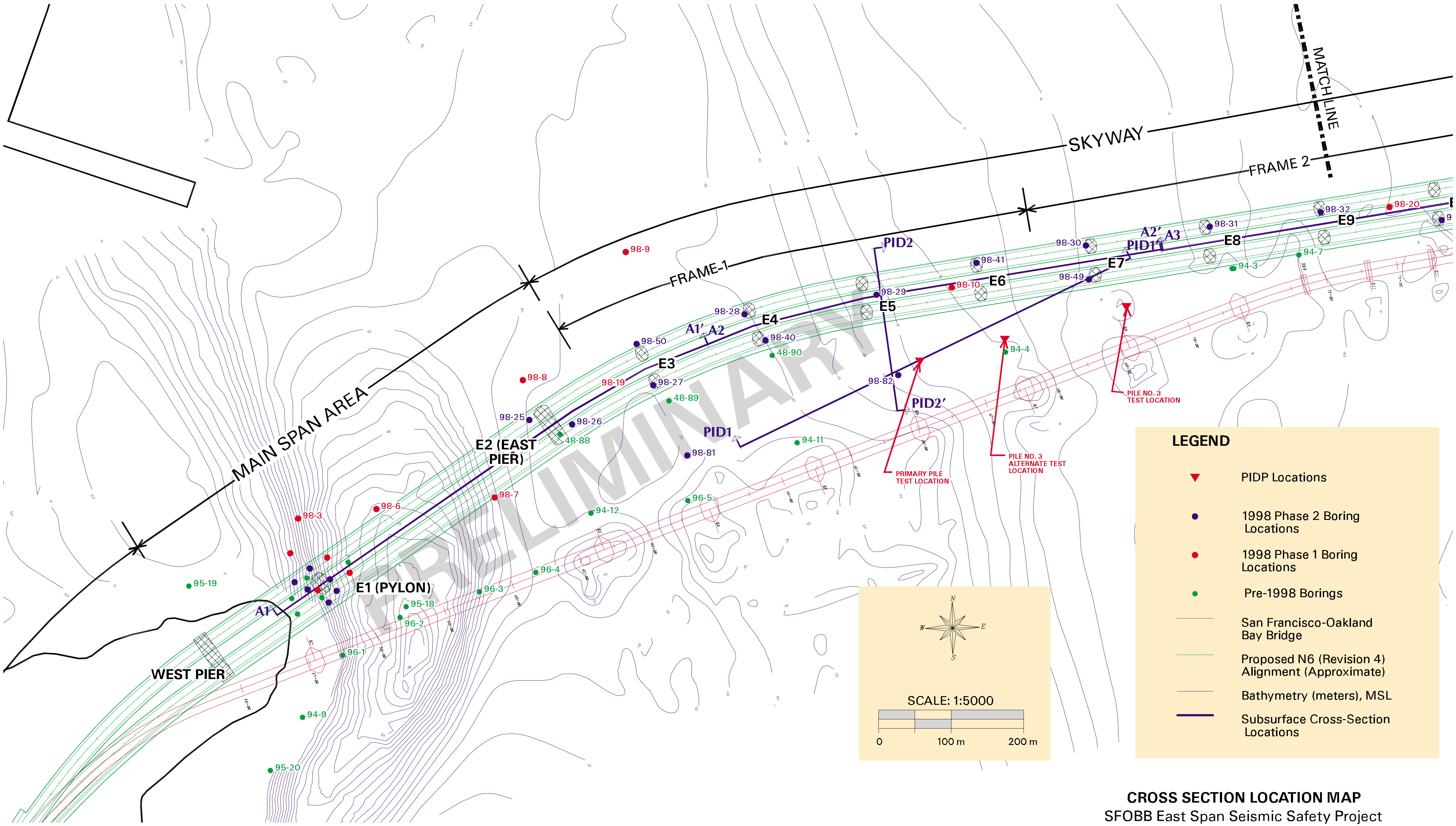
Project No. 98-42-0061



CROSS SECTION LOCATION MAP
SFOBB East Span Seismic Safety Project

PLATE 2a

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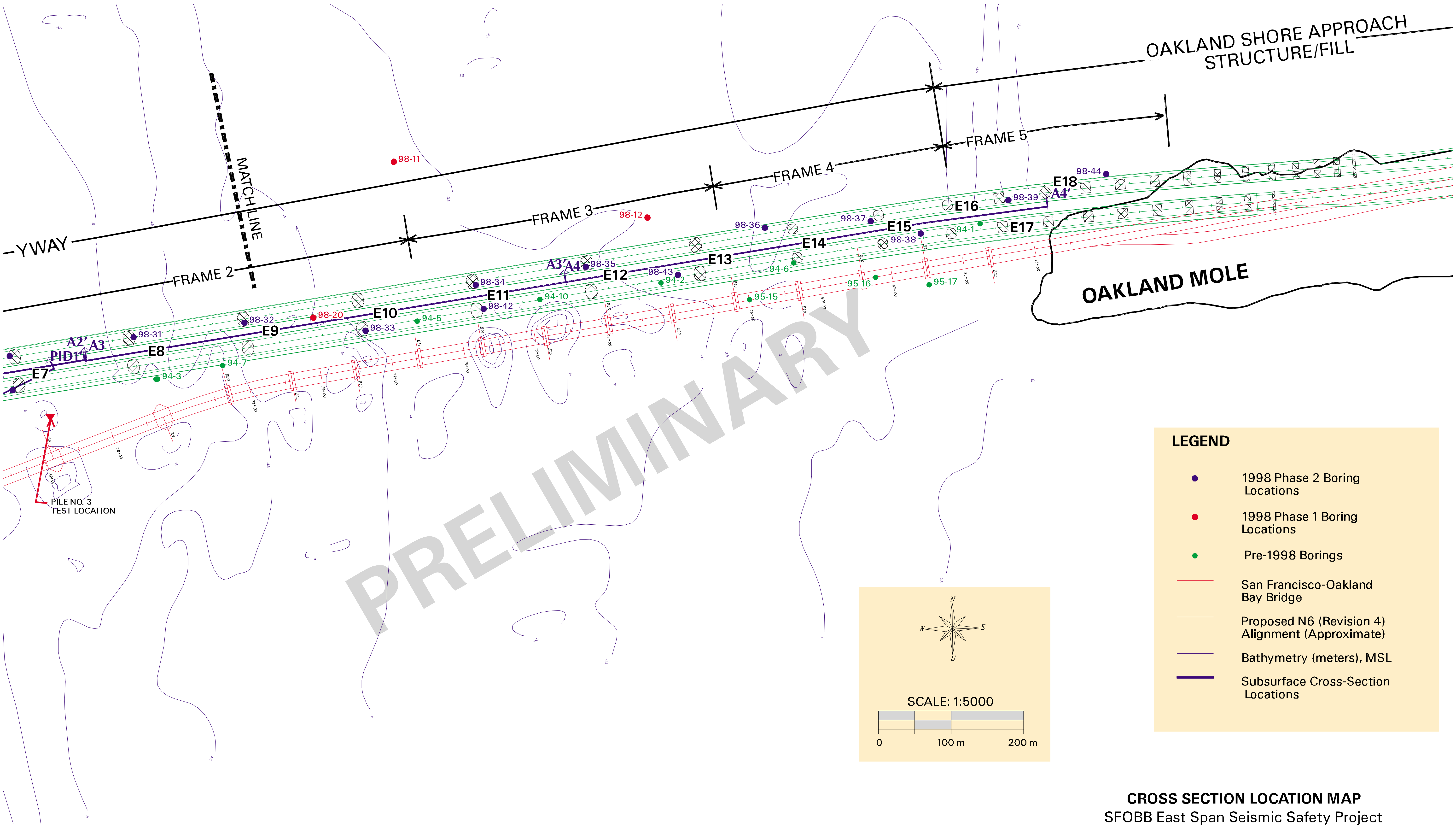


LEGEND

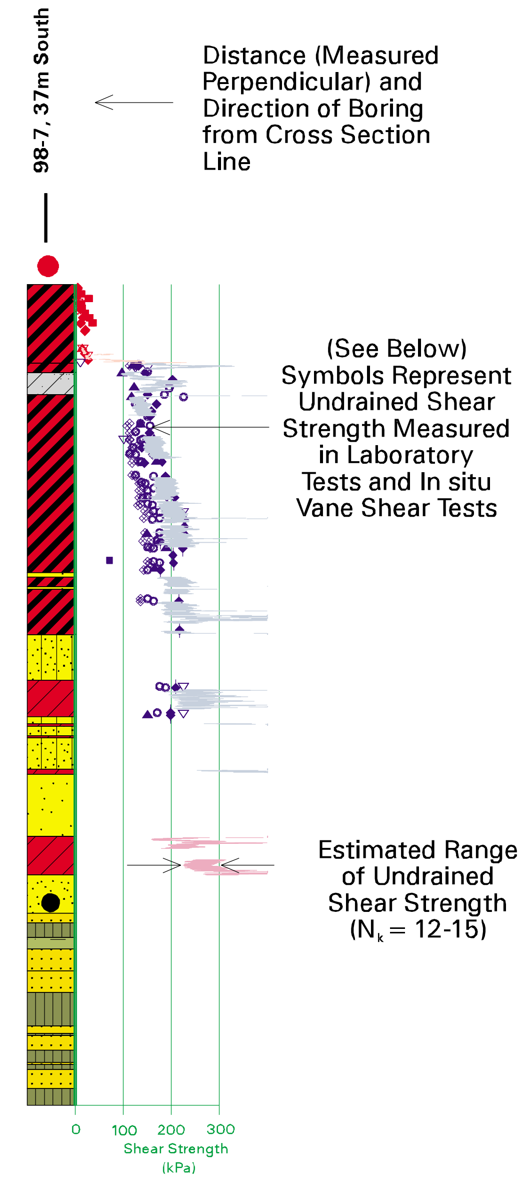
- 1998 Phase 2 Boring Locations
- 1998 Phase 1 Boring Locations
- Pre-1998 Borings
- San Francisco-Oakland Bay Bridge
- Proposed N6 (Revision 4) Alignment (Approximate)
- Bathymetry (meters), MSL
- Subsurface Cross-Section Locations

CROSS SECTION LOCATION MAP
SFOBB East Span Seismic Safety Project

PLATE 2b

Key to Soil Lithology Symbols

- Well graded GRAVEL (GW)
- Poorly graded GRAVEL (GP)
- GRAVEL with sand (GP or GW)
- GRAVEL with clay (GP-GC)
- Clayey GRAVEL (GC)
- GRAVEL with silt (GP-GM)
- Silty GRAVEL (GM)
- Well graded SAND (SW)
- Poorly graded SAND (SP)
- SAND with gravel (SP or SW)
- SAND with clay (SP-SC)
- Clayey SAND (SC)
- SAND with silt (SP-SM)
- Silty SAND (SM)
- Fat CLAY (CH)
- Sandy fat CLAY (CH)
- Lean CLAY (CL)
- Sandy lean CLAY (CL)
- Silty CLAY (CL-ML)
- Elastic SILT (MH)
- SILT (ML)
- Sandy SILT (ML)
- Clayey SILT (ML/CL)
- Highly Plastic ORGANICS (OH)
- Low plasticity ORGANICS (OL)
- SANDSTONE (Rx)
- SILTSTONE (Rx)
- CLAYSTONE (Rx)
- Interbedded Rock Strata (Rx)
- CONGLOMERATE (Rx)
- Rock Fragments
- PAVEMENT



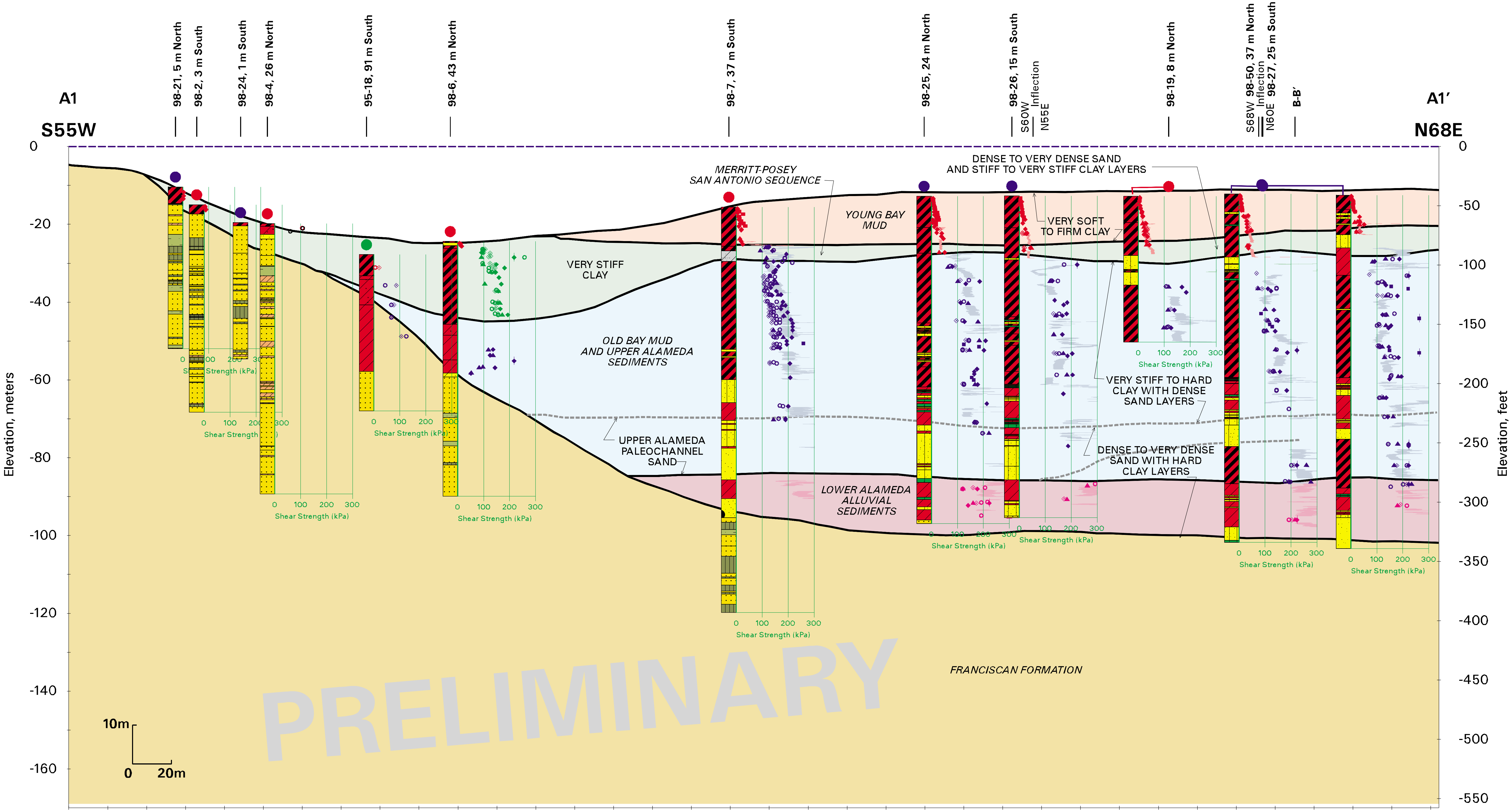
SOIL BORING LITHOLOGY WITH UNDRAINED SHEAR STRENGTH

Key to Undrained Shear Strength Symbols

- ▲ Unconsolidated Undrained (UU)
- △ Unconfined Compression (UC)
- ○ Pocket Penetrometer (PP)
- | Torvane (TV)
- ◆ Miniature Vane (MV)
- ■ Remote Vane (RV)

KEY TO CROSS SECTIONS
SFOBB East Span Seismic Safety Project

PLATE 3



GENERAL NOTES:

1) Stratigraphic contacts are approximate and are interpreted from lithology in borings, CPT soundings, and geologic structure imaged by geophysical survey. Conditions vary both along and perpendicular to the alignment.

2) Strata descriptions are generalized. Individual logs of borings and CPT soundings should be consulted for details.

3) Refer to Key to Cross Sections (Plate 3) for details of data plotted on cross-sections. Note that lithologies for pre-1998 boring logs are in some instances modified from those shown on Caltrans' Log of Test Boring Sheets. Modifications were made based on subsequent laboratory results and extrapolation from adjacent 1998 borings.

UNDRAINED SHEAR STRENGTH LEGEND

- ▲ Unconsolidated Undrained (UU)
- △ Unconfined Compression (UC)
- ○ Pocket Penetrometer (PP)
- ◈ Torvane (TV)
- ◆ Miniature Vane (MV)
- ■ Remote Vane (RV)

SUBSURFACE CROSS SECTION A1-A1′
With Undrained Shear Strength
SFOBB East Span Seismic Safety Project

PLATE 4

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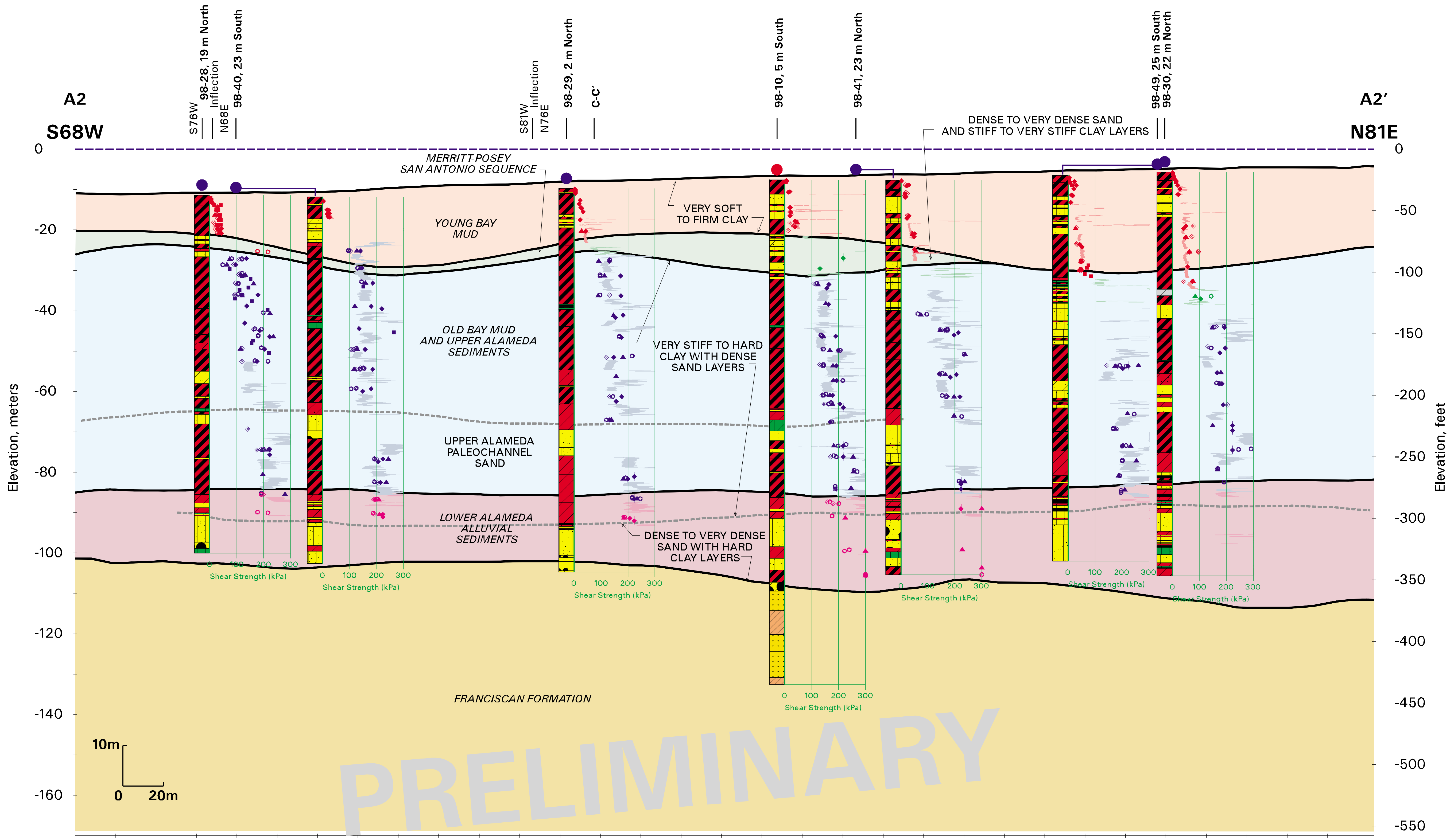

GENERAL NOTES:

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- ◈ Torvane (TV)
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- ■ Remote Vane (RV)

SUBSURFACE CROSS SECTION A2-A2′
With Undrained Shear Strength
SFOBB East Span Seismic Safety Project
PLATE 5

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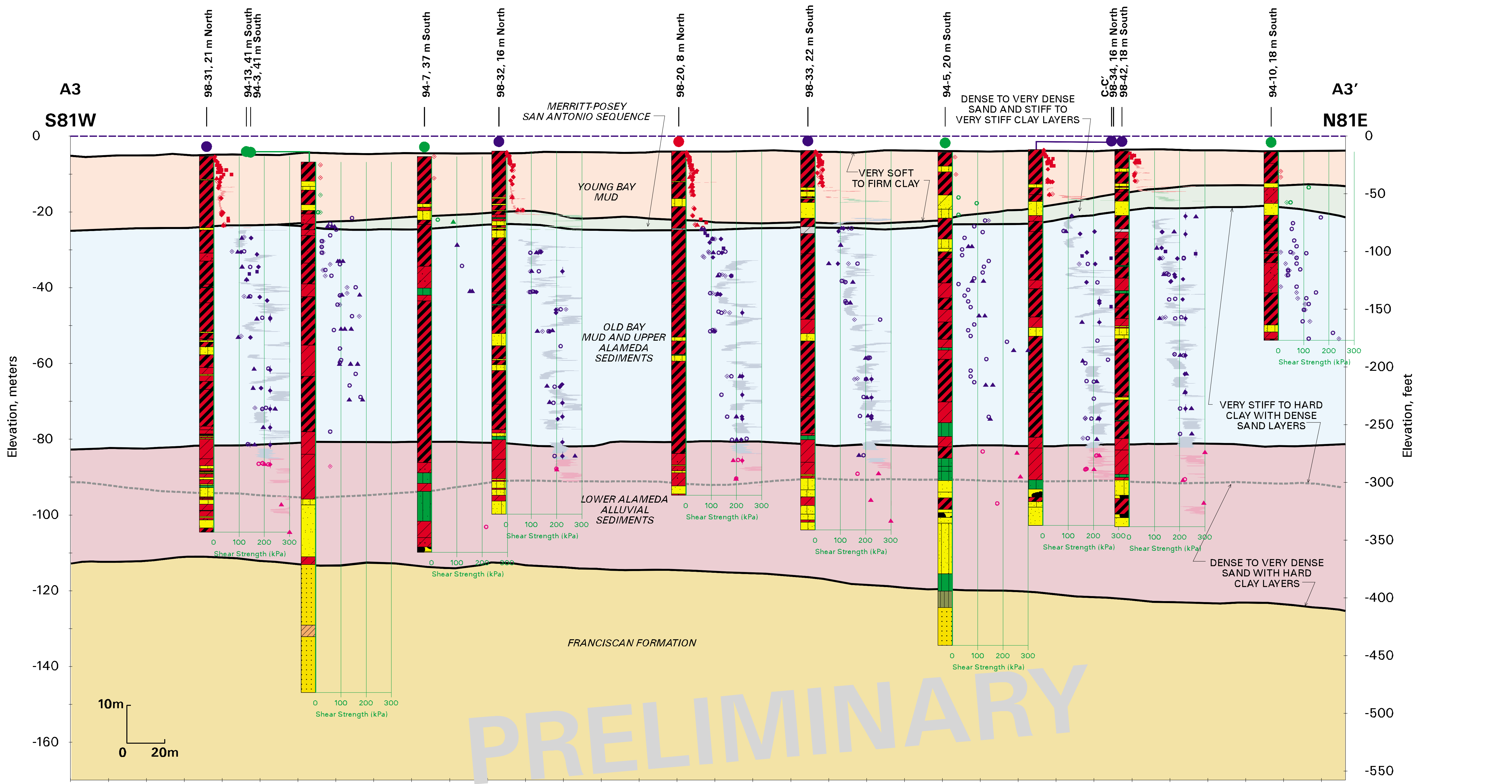
Project NO. 98-42-0061



GENERAL NOTES:

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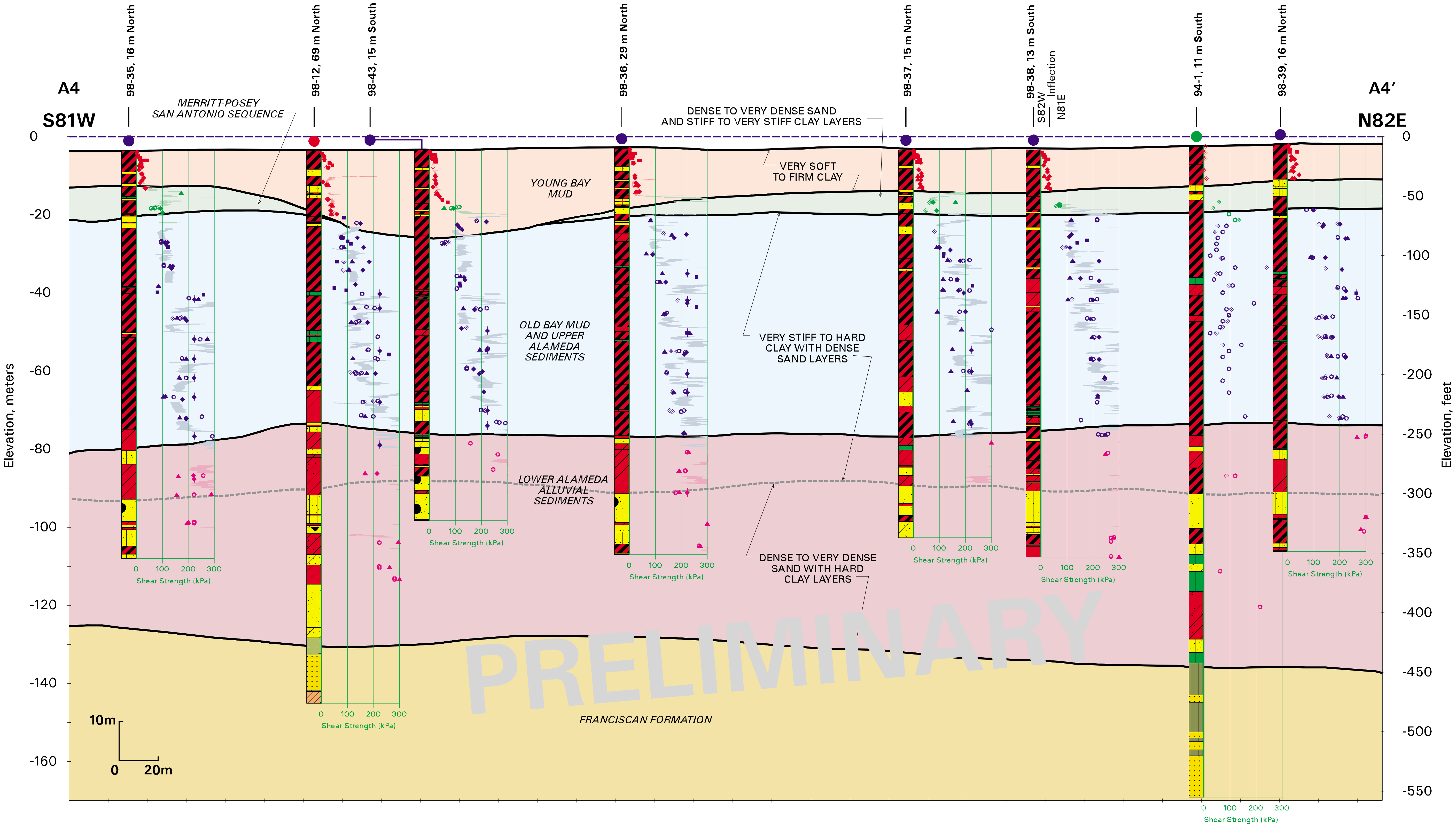
UNDRAINED SHEAR STRENGTH LEGEND

- ▲ Unconsolidated Undrained (UU)
- △ Unconfined Compression (UC)
- ○ Pocket Penetrometer (PP)
- ◈ Torvane (TV)
- ◆ Miniature Vane (MV)
- ■ Remote Vane (RV)

SUBSURFACE CROSS SECTION A3-A3'
With Undrained Shear Strength
SFOBB East Span Seismic Safety Project

PLATE 6

/bones/baymetric/profiles/sectall.aml, colrcta3.map, 06/19/99 CBD



GENERAL NOTES:

1) Stratigraphic contacts are approximate and are interpreted from lithology in borings, CPT soundings, and geologic structure imaged by geophysical survey. Conditions vary both along and perpendicular to the alignment.

2) Strata descriptions are generalized. Individual logs of borings and CPT soundings should be consulted for details.

3) Refer to Key to Cross Sections (Plate 3) for details of data plotted on cross-sections. Note that lithologies for pre-1998 boring logs are in some instances modified from those shown on Caltrans' Log of Test Boring Sheets. Modifications were made based on subsequent laboratory results and extrapolation from adjacent 1998 borings.

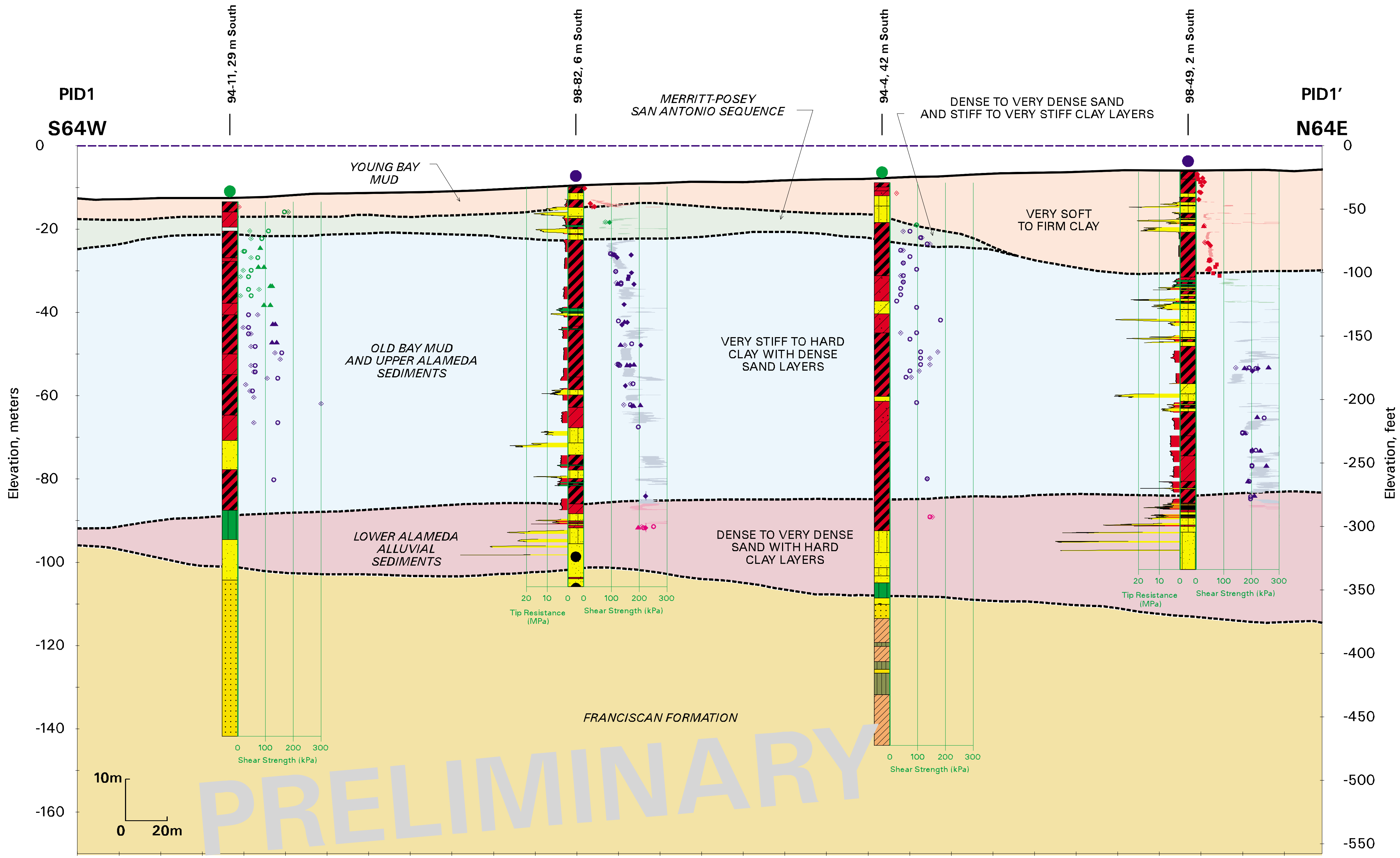
UNDRAINED SHEAR STRENGTH LEGEND

- ▲ Unconsolidated Undrained (UU)
- △ Unconfined Compression (UC)
- ○ Pocket Penetrometer (PP)
- ◇ Torvane (TV)
- ◆ Miniature Vane (MV)
- ■ Remote Vane (RV)

SUBSURFACE CROSS SECTION A4-A4'
With Undrained Shear Strength
SFOBB East Span Seismic Safety Project

PLATE 7

SFOBB Task Order No. 6
Project No. 98-42-0061



GENERAL NOTES:

1) Stratigraphic contacts are approximate and are interpreted from lithology in borings, CPT soundings, and geologic structure imaged by geophysical survey. Conditions vary both along and perpendicular to the alignment.

2) Strata descriptions are generalized. Individual logs of borings and CPT soundings should be consulted for details.

3) Refer to Key to Cross Sections (Plate 3) for details of data plotted on cross-sections. Note that lithologies for pre-1998 boring logs are in some instances modified from those shown on Caltrans' Log of Test Boring Sheets. Modifications were made based on subsequent laboratory results and extrapolation from adjacent 1998 borings.

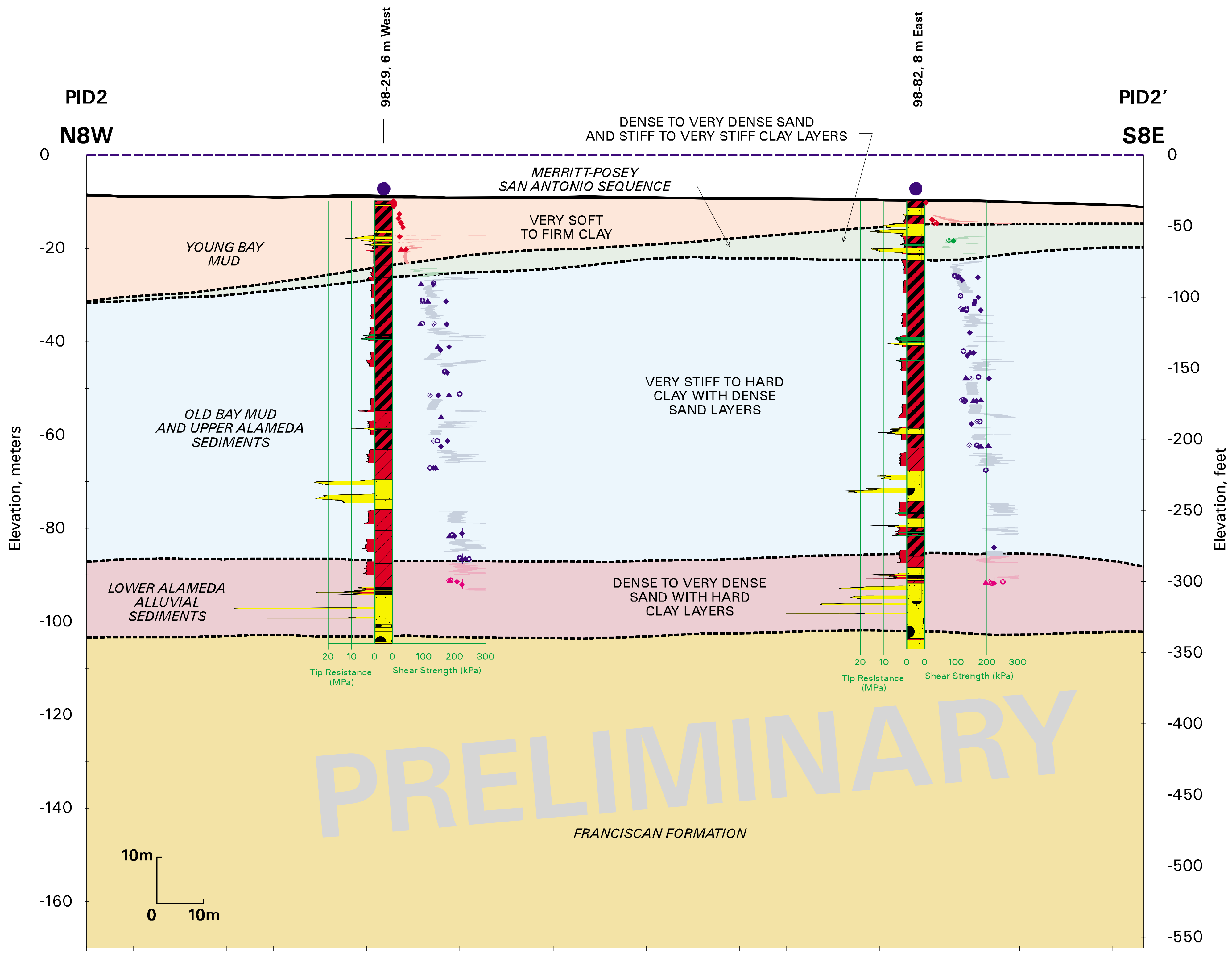
UNDRAINED SHEAR STRENGTH LEGEND

- ▲ Unconsolidated Undrained (UU)
- △ Unconfined Compression (UC)
- ○ Pocket Penetrometer (PP)
- ◈ Torvane (TV)
- ◆ Miniature Vane (MV)
- ■ Remote Vane (RV)

SUBSURFACE CROSS SECTION PID1-PID1′
With Undrained Shear Strength
SFOBB East Span Seismic Safety Project

PLATE 8

SFOBB Task Order No. 6
Project NO. 98-42-0061



GENERAL NOTES:
1) Stratigraphic contacts are approximate and are interpreted from lithology in borings, CPT soundings, and geologic structure imaged by geophysical survey. Conditions vary both along and perpendicular to the alignment.
2) Strata descriptions are generalized. Individual logs of borings and CPT soundings should be consulted for details.
3) Refer to Key to Cross Sections (Plate 3) for details of data plotted on cross-sections. Note that lithologies for pre-1998 boring logs are in some instances modified from those shown on Caltrans' Log of Test Boring Sheets. Modifications were made based on subsequent laboratory results and extrapolation from adjacent 1998 borings.

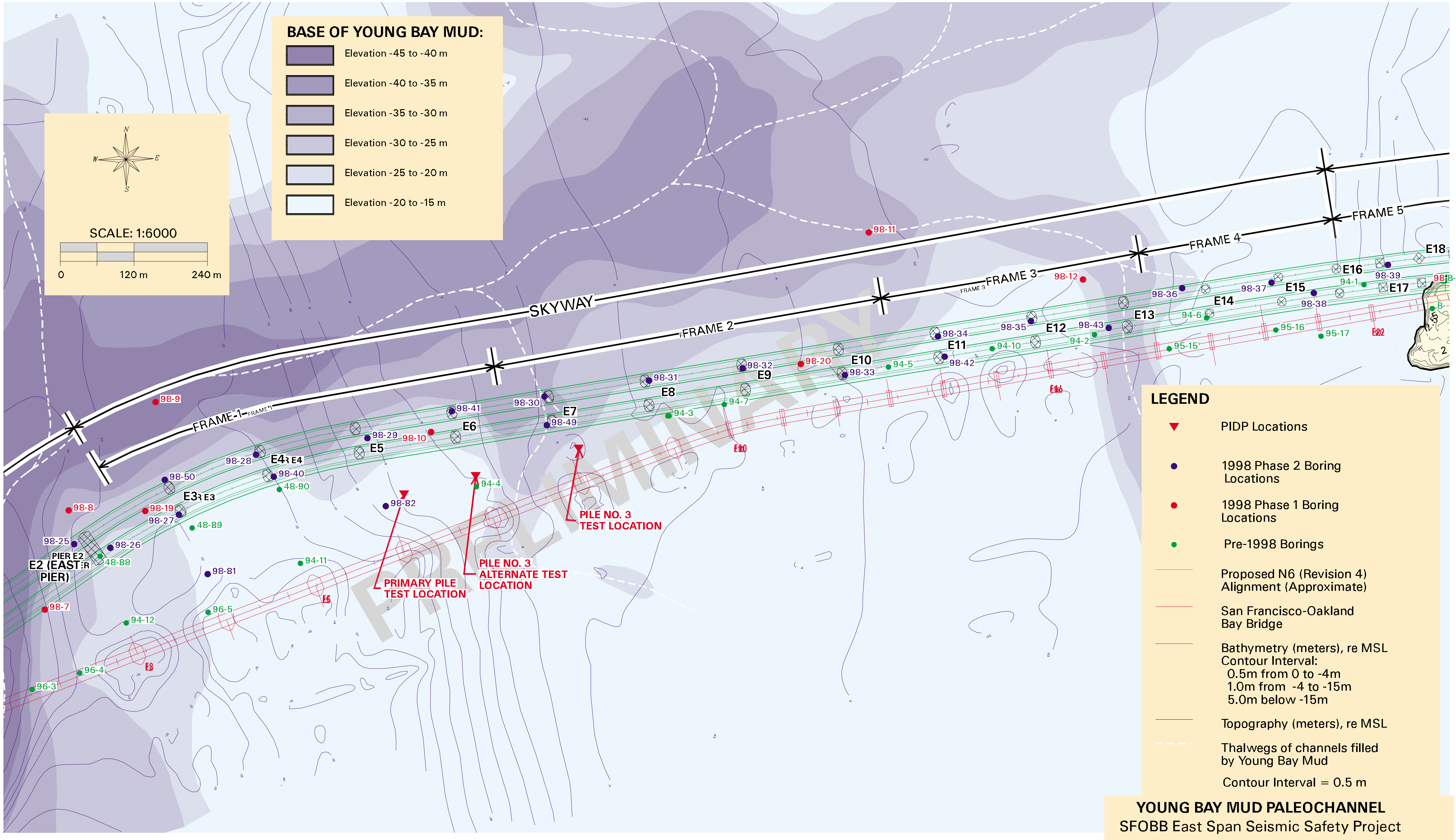
UNDRAINED SHEAR STRENGTH LEGEND

- ▲ Unconsolidated Undrained (UU)
- △ Unconfined Compression (UC)
- ○ Pocket Penetrometer (PP)
- ◈ Torvane (TV)
- ◆ Miniature Vane (MV)
- ■ Remote Vane (RV)

SUBSURFACE CROSS SECTION PID2-PID2′
With Undrained Shear Strength
SFOBB East Span Seismic Safety Project

PLATE 9

/bones/baymetric/explcovs/sectall.aml, /bones/baymetric/strat/colrpid2.map, 06/21/99 CBD



YOUNG BAY MUD PALEOCHANNEL
SFOBB East Span Seismic Safety Project

/bones/baymetric/maps/fndmap.aml, fndmap5.map, 07/02/99 CBD, 98-42-0061

PROJECT MEMORANDUM, FACTUAL SOILS DATA, BORINGS 98-49 AND 98-82, PID PROJECT, CALTRANS CONTRACT EA NO. 04-01208, DATED JULY 12, 1999

FUGRO WEST, INC.

5855 Olivas Park Drive
Ventura CA 93003-7672
Tel: (805) 650-7000
Fax: (805) 650-7010

July 12, 1999
Fugro Project No. 98-42-0061

PROJECT MEMORANDUM

To: Mr. Mark Willian, Caltrans (2 copies)
Mr. Reid Buell, Caltrans (3 copies)
Dr. Brian Maroney, Caltrans (1 copy)
Ms. Sharon Amlin Naramore, Caltrans (1 copy)

From: Messrs. Philip Robins and Tony Dover, P.E., Fugro

Subject: **Factual Soils Data, Borings 98-49 and 98-42, PID Project, Caltrans Contract EA No. 04-01208**

Purpose and Background

This memorandum presents the factual soils data collected at the Installation Demonstration Project locations for Borings 98-82 and 98-49. The two borings were drilled as part of the Task Order No. 5, Final Marine Site Characterization work scope.

Geotechnical Site Characterization Synopsis

A description of the marine drilling, sampling, in situ testing, downhole logging, and onboard laboratory testing equipment and procedures is included in Section 3.0 of the Preliminary Marine Geotechnical Site Characterization Report (Fugro-EM, 1998[1]). The locations of the borings are provided on Plate A-1, and details of the individual borings are included in the enclosed appendices.

Individual Boring Appendices

Individual boring appendices are provided for each of the two borings. Each boring appendix includes various in situ, downhole, and laboratory data.

Boring Appendices Collation and Plate Number Guide

The individual appendix plates are numbered with the boring number and non-sequential numbers (e.g., 98-49.2, 98-49.10a, etc.). Table 1 (provided at the end of this memorandum) shows the plate titles and numbers included in each boring-specific appendix. The boring logs

[1] Fugro-Earth Mechanics (Fugro-EM) (1998), *Preliminary Marine Geotechnical Site Characterization, Volumes 1, Section 3.0,* FWI Job No. 98-42-0035, prepared for California Department of Transportation, June 23.

listed in Table 1 have been intentionally removed since those data are shown on the Log of Test Boring sheets in the project plans.

Summary of Field Operations and Location/Depth Information

A description of the progress of the individual borings and a chart showing boring location, coordinates, depths (mudline, top of rock, bottom of borings, etc.), and corresponding elevations (re: Mean Sea Level [MSL] datum, as specified by Caltrans) are included at the beginning of each boring appendix.

Log of Test Borings

The log of test borings (LOTBs) for each marine boring included in the Contract Plans provide lithology descriptions, show sampling depths, contain descriptions of the soil and rock characteristics, and provide remote vane, laboratory, and downhole geophysical test data, and CPT data from the referenced borings.

Geotechnical Test Data. Sampler types are shown in the legend on the LOTBs. The following nomenclature applies to the information in the blow count column of the log: a) "PUSH" denotes thin-wall tube samples pushed with the weight of the drill pipe; b) "WOH" denotes liner samplers advanced by the weight of the down-hole hammer; c) values such as 18 designate either Standard Penetration Test (SPT) N-values or California modified sampler; d) 50/7.5cm is a SPT N-value; and e) 30/60cm is a downhole, wireline hammer blow count. Additional description of the blow count and sampler nomenclature is provided on the legend of the LOTBs.

The ID Tests/Eq. Blow Counts column of the LOTB provides water content, plastic limit, liquid limit, percent passing the number 200 sieve, and density measurements (presented as submerged unit weights). In addition to the direct measurements of density, the logs also show the theoretical submerged unit weight based on the measured water content, an assumed specific gravity of 2.7, and an assumed 100-percent saturation. In rock intervals, the recovery, RQD, and coring rate are plotted in the center column of the log.

The Soil Undrained Shear Strength column presents the results of the undrained shear strength measurements conducted on samples recovered from the borings as well as the strengths measured in situ using the Halibut and Dolphin remote vane tools. The range of undrained shear strengths that are calculated from CPT cone tip resistances (corrected for unequal end area effects) also are shown based on cone bearing capacity (N_k values) of 12 and 15. Undrained shear strengths measured on remolded samples also are included in the plotted data.

In rock intervals, the unconfined compressive strength measured in unconfined tests and estimated from point load tests are plotted in the right-hand column. Fracture density also is plotted in the rock intervals.

CPT Data. The in situ CPTs were conducted downhole using the Dolphin system. This downhole in situ tool has a maximum stroke (or test length) of 3 meters. Data are acquired in 3-meter-long increments, or until the CPT meets refusal. The CPT intervals were interspersed with soil sampling.

Each LOTB provides graphical plots of the CPT data versus depth below mudline (or bay bottom). Data that are shown include: a) tip resistance in megapascals (MPa), b) sleeve friction in MPa, c) excess pore pressure readings in MPa, and d) friction ratio in percent.

Downhole Geophysical Data. Downhole geophysical tests were conducted in the two marine borings. That testing was conducted to measure compression and shear wave velocity (Vp and Vs, respectively).

Laboratory Test Results

The offshore and onshore laboratory test results are incorporated in the LOTBs. In addition to the test data plotted on the LOTBs (provided in the Contract Plans), the appendices include the following information (where relevant):

- Tabulated summary of test results
- Grain size distribution curves
- Plasticity chart showing the Atterberg limit data

Soil Property Profiles

Where data are available, the following soil properties are plotted versus depth:

- Plasticity Index (Liquid Limit minus Plastic Limit)
- Liquidity Index ([water content minus Plastic Limit] divided by Plasticity Index)
- Soil Sensitivity (undisturbed shear strength divided by remolded shear strength)
- ε_{50} (strain at 50 percent of the failure stress in UU triaxial tests)
- Preconsolidation Pressure - The interpreted preconsolidation pressure profiles show interpreted preconsolidation pressures from consolidation tests and estimated preconsolidation pressures from the in situ CPT data. Also shown on those plots are the calculated effective overburden pressure and isochrones of calculated overconsolidation ratios (OCR).
- Relative Density from CPT test data (marine borings)

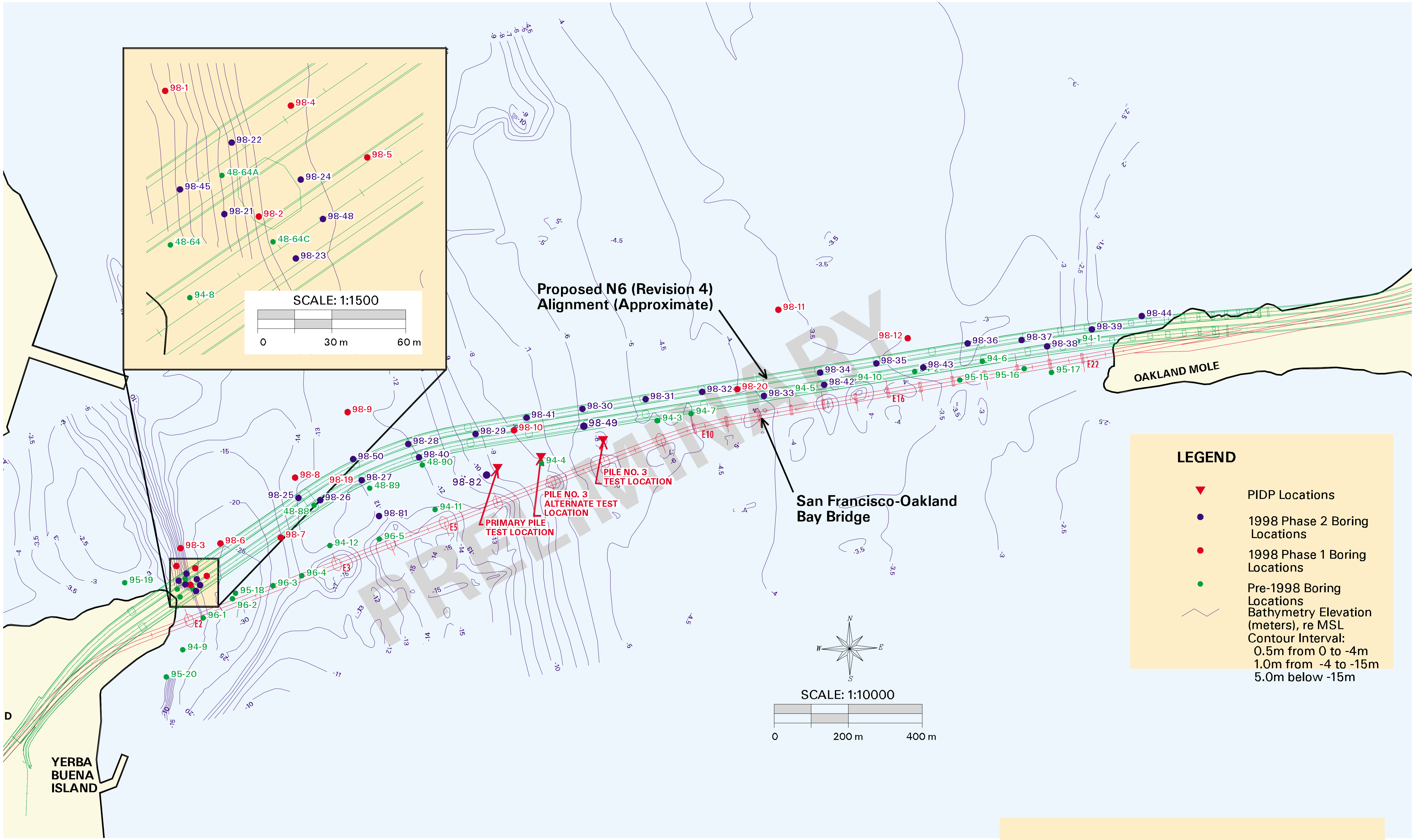
Attachments: Table 1 - Boring-Specific Appendix Plate Numbering Guide
Plate A-1 - Bathymetry and Marine Explorations
Plates for Boring 98-49
Plates for Boring 98-82

Table 1. Boring-Specific Appendix Plate Numbering Guide

Contents	Plate Numbers	
	Boring 98-49	Boring 98-82
Summary of Field Operations	98-49.1	98-82.1
Boring Depth and Location Reference Map	98-49.2	98-82.2
Boring Logs:		
Single page boring logs with soil and rock test results	*	*
Single page boring logs with CPT data	*	*
Single page boring logs with suspension logging data	*	*
Multi-page boring logs with soil and rock test results	*	*
Multi-page boring logs with CPT data	*	*
Log of near-surface materials	*	*
Laboratory Test Results:		
Summary of laboratory test results	98-49.10a-g	98-82.10a-f
Grain size distribution curves	98-49.11a-d	98-82.11a-c
Plasticity chart	98-49.12	98-82.12
Stress-strain curves	*	*
CRS/Incremental consolidation test results	*	*
Ko-Consolidated undrained triaxial compression test results	*	*
Consolidated-drained triaxial compression test results	*	*
Soil Property Profiles:		
Plasticity index	98-49.17	98-82.17
Liquidity index	98-49.18	98-82.18
Soil sensitivity	98-49.19	98-82.19
ε_{50}	98-49.20	98-82.20
Preconsolidation stress	98-49.21	98-82.21
Relative density	98-49.22	98-82.22

* Plates provided under separate cover (Fugro-EM, 1999[2])

SFOBB Task Order No. 6
Project No. 98-42-0061



BATHYMETRY AND MARINE EXPLORATIONS
SFOBB East Span Seismic Safety Project

PLATE A-1

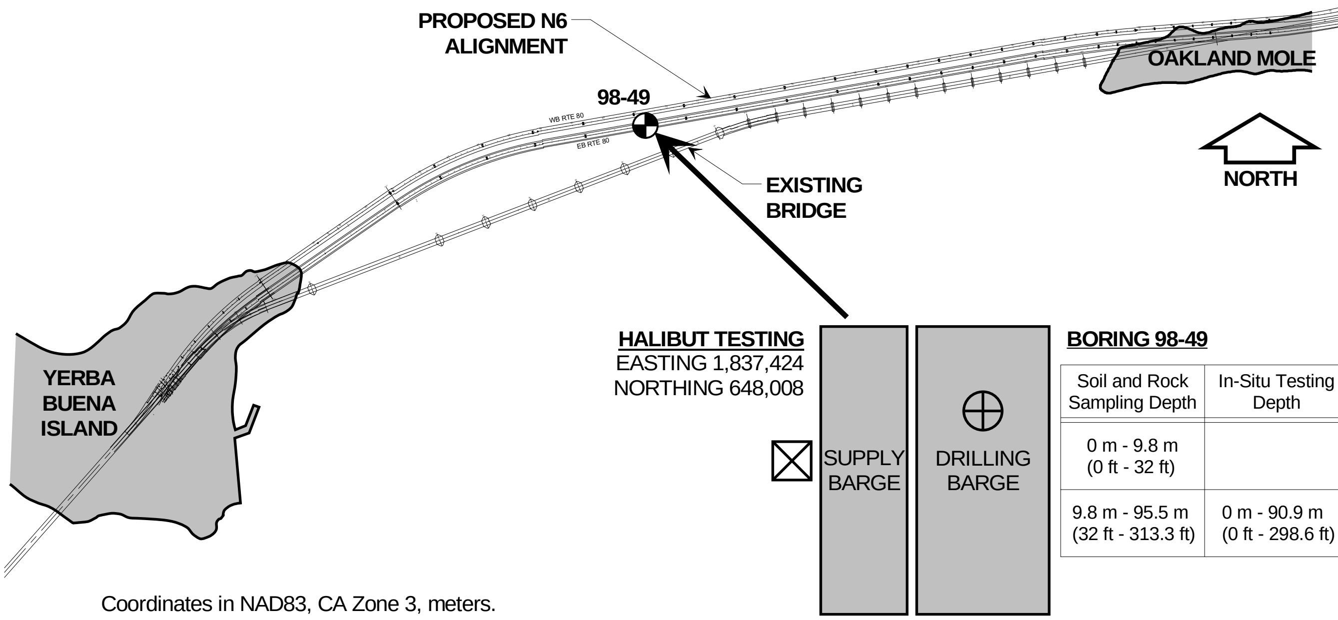
/bones/baymetric/maps/borinset.aml, borins7.map, 03/02/00 CBD, 98-42-0061

BORING 98-49

Date	Time From	Time To	Description of Activity
November 19, 1998	0700	0850	Move barge to location 98-49. Set 4 anchors and 2 spuds.
	0850	0930	Rig up for drilling. Lower drill pipe to mudline.
	0930	0940	Measure water depth of 7m (22.8 ft) using bottom sensor. Current tide level is approximately 0.7m (2.4 ft) MSL. Calculate mudline elevation of -6.2m (-20.4 ft) MSL.
	0940	1200	Drill and sample from mudline to 9.8m (32 ft).
	1200	1230	Pull drill pipe to deck. Reposition barge.
	****	****	
	1230	1530	Rig up Halibut vane equipment. Perform Halibut vane shear testing from 0.6m (2 ft) to 2.4m (8 ft) using large blades.
	****	****	
	1230	1430	Set casing and level barge.
	1430	1545	Set casing.
	1545	2000	Drive stinger to 8.4m (27.5 ft).
	2000	2210	Service thruster. Lower drill pipe to mudline.
	2210	2400	Drill, sample, and CPT testing from mudline to 9.8m (32 ft).
November 20, 1998	0000	1215	Drill, sample, remote vane shear, and CPT testing from 9.8m (32 ft) to 62.2m (204 ft).
	****	****	
	0000	0530	Perform Halibut vane shear testing from 0.6m (2 ft) to 2.4m (8 ft) using medium blades.
	****	****	
	1215	1650	Drill, sample, and CPT testing from 62.2m (204 ft) to 82.3m (270 ft).
	1650	1720	Drill, sample, and CPT testing from 82.3m (270 ft) to 84.4m (277 ft).
	1720	2015	Wait on extreme low tide.
	2015	2400	Drill, sample, and CPT testing from 84.4m (277 ft) to 93.9m (308 ft).
November 21, 1998	0000	0100	Drill, sample, and CPT testing from 93.9m (308 ft) to 95.5m (313.3 ft)
	0100	0200	Pull drill pipe to deck.
	0200	0420	P- and S-wave velocity logging from 89.0m (292 ft) to 7.5m (24.6 ft).
	0420	0545	Lower N-rod. Mix and circulate cement. Grout hole 98-49.
	0545	0610	Pull N-rod to deck.
	0610	1000	Pull casing to deck.
	1000	1300	Perform maintenance on rig and barge.
	1300	1520	Pull 2 spuds, 4 anchors, and travel to CS Marine yard, Mare Island.

SUMMARY OF FIELD OPERATIONS
Boring 98-49
SFOBB East Span Seismic Safety Project

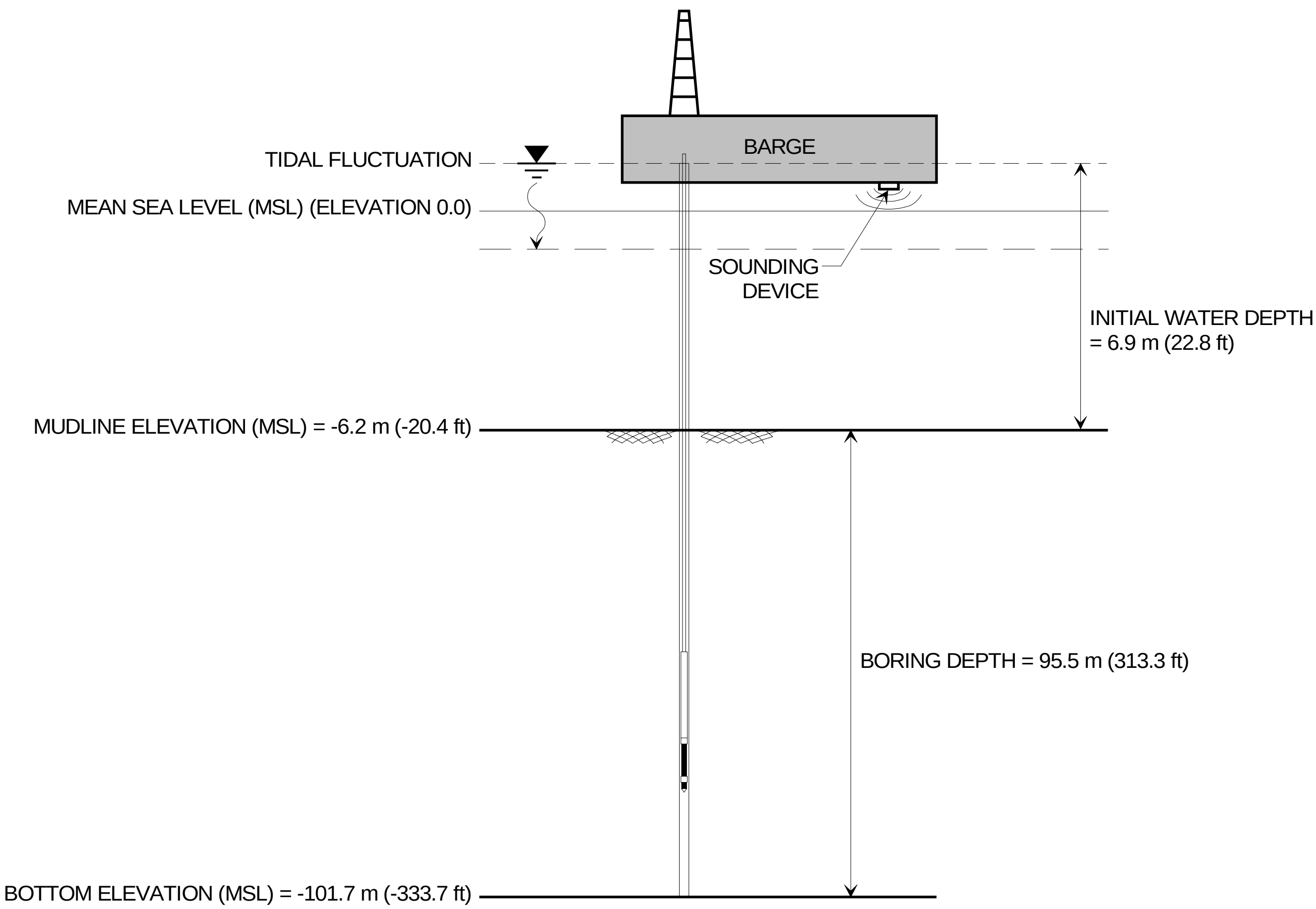
SFOBB Task Order No. 5
Project No. 98-42-0054



BORING 98-49

Soil and Rock Sampling Depth	In-Situ Testing Depth	Coordinates
0 m - 9.8 m (0 ft - 32 ft)		E = 1,837,442 N = 648,012
9.8 m - 95.5 m (32 ft - 313.3 ft)	0 m - 90.9 m (0 ft - 298.6 ft)	E = 1,837,438 N = 648,013

Coordinates in NAD83, CA Zone 3, meters.



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DEPTH AND LOCATION REFERENCE MAP
Boring 98-49
SFOBB East Span Seismic Safety Project

PLATE 98-49.2

98-49 DEPTH (m)	Sample No.	IDENTIFICATION TESTS MC (%)	LL (%)	PL (%)	LI	SUW (kN/m3)	Fines (%)	STRENGTH ESTIMATE Torvane (kPa)	Pocket Pen. (kPa)	Fall Cone (kPa)	MINIATURE VANE TESTS Undist. (kPa)	Remold. (kPa)	Resid. (kPa)	REMOTE VANE (kPa)	UU TRIAXIAL Undist. (kPa)	Remold. (kPa)	e50 (%)	MULTI-STAGE TRIAXIAL c (kPa)	phi (deg)	DIRECT SHEAR TESTS Peak c (kPa)	Peak phi (deg)	Post Peak c (kPa)	Post Peak phi (deg)	ADDITIONAL TESTS	MAX DEN (kN/m3)	MIN DEN (kN/m3)
0.3	1					4.4																				
0.5	2	94	76	30	1.41	4.6																				
0.6	3									2.0	4.5		1.1													
0.6	400													1.9												
0.6	401													2.9												
1.2	4					4.7																				
1.2	402													5.3												
1.2	403													5.3												
1.4	5	65	75	30	0.79	4.3	71																	H		
1.5	6									11.5	24.2															
1.8	404													8.1												
1.8	405													7.7												
2.1	7					6.3																				
2.3	8	44	52	22	0.72	6.5	99																	H		
2.4	9									15.3	29.9		9.8													

Identification Tests
MC = Moisture Content
LL = Liquid Limit
PL = Plastic Limit
LI = Liquidity Index

Identification Tests
SUW = Submerged Unit Weight
Fines = % Passing No. 200 Sieve

Strength Tests
UU = Unconsolidated Undrained
e50 = Strain at 50% Failure Stress
c = Effective Cohesion
phi = Effective Angle of Friction

Additional Tests
H = Hydrometer
C = Consolidation Test
RC = Resonant Column
CS = Cyclic Simple Shear

Additional Tests
K = Ko Consolidated Triaxial Test

SUMMARY OF LABORATORY TEST RESULTS
Boring 98-49
SFOBB East Span Seismic Safety Project

98-49		IDENTIFICATION TESTS						STRENGTH ESTIMATE			MINIATURE VANE TESTS			REMOTE VANE (kPa)	UU TRIAXIAL			MULTI-STAGE TRIAXIAL		DIRECT SHEAR TESTS				ADDITIONAL TESTS	MAX DEN (kN/m3)	MIN DEN (kN/m3)
DEPTH (m)	Sample No.	MC (%)	LL (%)	PL (%)	LI	SUW (kN/m3)	Fines (%)	Torvane (kPa)	Pocket Pen. (kPa)	Fall Cone (kPa)	Undist. (kPa)	Remold. (kPa)	Resid. (kPa)		Undist. (kPa)	Remold. (kPa)	e50 (%)	c (kPa)	phi (deg)	Peak c (kPa)	Peak phi (deg)	Post Peak c (kPa)	Post Peak phi (deg)			
2.4	406													16.3												
2.4	407													14.8												
3.0	10					8.7																				
3.2	11					8.3																				
3.4	12	36	36	19	0.97		48			15.3	21.6	5.8														
4.9	13					5.5					11.8	5.1														
5.0	14	75	57	27	1.60	5.8																				
5.2	15										17.5	5.8														
5.8	16						20											4.8	34							
5.9	17					10.0																				
6.1	18	37					12																			
6.7	20					7.2					9.8															
7.6	23					10.9																				
7.8	24	20																								
8.4	25					10.5	12											9.6	37							

Identification Tests
MC = Moisture Content
LL = Liquid Limit
PL = Plastic Limit
LI = Liquidity Index

Identification Tests
SUW = Submerged Unit Weight
Fines = % Passing No. 200 Sieve

Strength Tests
UU = Unconsolidated Undrained
e50 = Strain at 50% Failure Stress
c = Effective Cohesion
phi = Effective Angle of Friction

Additional Tests
H = Hydrometer
C = Consolidation Test
RC = Resonant Column
CS = Cyclic Simple Shear

Additional Tests
K = Ko Consolidated Triaxial Test

SUMMARY OF LABORATORY TEST RESULTS
Boring 98-49
SFOBB East Span Seismic Safety Project

98-49		IDENTIFICATION TESTS						STRENGTH ESTIMATE			MINIATURE VANE TESTS			REMOTE VANE (kPa)	UU TRIAXIAL			MULTI-STAGE TRIAXIAL		DIRECT SHEAR TESTS				ADDITIONAL TESTS	MAX DEN (kN/m3)	MIN DEN (kN/m3)
DEPTH (m)	Sample No.	MC (%)	LL (%)	PL (%)	LI	SUW (kN/m3)	Fines (%)	Torvane (kPa)	Pocket Pen. (kPa)	Fall Cone (kPa)	Undist. (kPa)	Remold. (kPa)	Resid. (kPa)		Undist. (kPa)	Remold. (kPa)	e50 (%)	c (kPa)	phi (deg)	Peak c (kPa)	Peak phi (deg)	Post Peak c (kPa)	Post Peak phi (deg)			
8.5	26	40					14																			
9.3	27					10.6	15											9.6	36						17.4	13.7
9.3	29	18					12																			
9.4	28						23																			
9.5	30					10.8																				
13.0	31	63	51	21	1.40	7.6		29.7							28.2		0.8									
13.1	32					9.5	5											9.6	41							
13.3	33	21					14																			
16.9	35	53	63	27	0.72	6.3		31.6																		
17.1	36							33.5		49.8	42.8															
17.6	37	55	59	24	0.90																			C		
17.7	38	58	72	32	0.66						52.1															
21.2	40	51	57	24	0.82	6.6		52.7	47.9						47.8	10.9	0.9									
21.3	41							49.8	47.9	62.2	49.0															
22.3	500													75.2												

Identification Tests
MC = Moisture Content
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Identification Tests
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Additional Tests
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Additional Tests
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SUMMARY OF LABORATORY TEST RESULTS
Boring 98-49
SFOBB East Span Seismic Safety Project

98-49		IDENTIFICATION TESTS						STRENGTH ESTIMATE			MINIATURE VANE TESTS			REMOTE VANE (kPa)	UU TRIAXIAL			MULTI-STAGE TRIAXIAL		DIRECT SHEAR TESTS				ADDITIONAL TESTS	MAX DEN (kN/m3)	MIN DEN (kN/m3)
DEPTH (m)	Sample No.	MC (%)	LL (%)	PL (%)	LI	SUW (kN/m3)	Fines (%)	Torvane (kPa)	Pocket Pen. (kPa)	Fall Cone (kPa)	Undist. (kPa)	Remold. (kPa)	Resid. (kPa)		Undist. (kPa)	Remold. (kPa)	e50 (%)	c (kPa)	phi (deg)	Peak c (kPa)	Peak phi (deg)	Post Peak c (kPa)	Post Peak phi (deg)			
22.9	501													69.9												
23.2	42	56	69	33	0.64																			C		
23.3	43					5.9		47.9	47.9						42.5		0.9									
23.5	44							43.1	47.9	66.1	49.0															
24.4	502													61.8												
25.0	503													84.7												
25.5	46	21	31	13	0.45	9.6	36																			
25.6	47									197.3																
29.4	48	18	66	35		8.8																				
29.5	49						7																			
29.6	50	27																								
34.6	51					9.4	15											33.5	30							
34.7	52	21					19																			
38.3	53	27					9																			
41.9	54					10.8																				

Identification Tests
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SUW = Submerged Unit Weight
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Additional Tests
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C = Consolidation Test
RC = Resonant Column
CS = Cyclic Simple Shear

Additional Tests
K = Ko Consolidated Triaxial Test

SUMMARY OF LABORATORY TEST RESULTS
Boring 98-49
SFOBB East Span Seismic Safety Project

SFOBB Task Order No. 5
Project No. 98-42-0054

98-49		IDENTIFICATION TESTS						STRENGTH ESTIMATE			MINIATURE VANE TESTS			REMOTE VANE (kPa)	UU TRIAXIAL			MULTI-STAGE TRIAXIAL		DIRECT SHEAR TESTS				ADDITIONAL TESTS	MAX DEN (kN/m3)	MIN DEN (kN/m3)
DEPTH (m)	Sample No.	MC (%)	LL (%)	PL (%)	LI	SUW (kN/m3)	Fines (%)	Torvane (kPa)	Pocket Pen. (kPa)	Fall Cone (kPa)	Undist. (kPa)	Remold. (kPa)	Resid. (kPa)		Undist. (kPa)	Remold. (kPa)	e50 (%)	c (kPa)	phi (deg)	Peak c (kPa)	Peak phi (deg)	Post Peak c (kPa)	Post Peak phi (deg)			
42.0	55	17																								
42.0	55	26																								
46.9	56	31	70	30	0.03										261.4		1.0									
47.1	57	31	51	18	0.40	9.1		143.6	191.5						175.2	80.8	1.2									
47.2	58							181.9	215.5		222.8															
47.8	59	36	55	23	0.41																			C		
47.9	60	39	63	26	0.35						203.0															
52.3	61	13					31																			
52.4	62					11.5																				
55.0	63	26					15																			
58.8	64	38	88	29	0.16										220.4	199.3	0.4									
59.0	65					7.8																				
59.1	66								245.3																	
62.6	68	47	78	24	0.43	7.5			167.6						175.7	64.4	0.3									
62.8	69							179.6	167.6																	

Identification Tests
MC = Moisture Content
LL = Liquid Limit
PL = Plastic Limit
LI = Liquidity Index

Identification Tests
SUW = Submerged Unit Weight
Fines = % Passing No. 200 Sieve

Strength Tests
UU = Unconsolidated Undrained
e50 = Strain at 50% Failure Stress
c = Effective Cohesion
phi = Effective Angle of Friction

Additional Tests
H = Hydrometer
C = Consolidation Test
RC = Resonant Column
CS = Cyclic Simple Shear

Additional Tests
K = Ko Consolidated Triaxial Test

SUMMARY OF LABORATORY TEST RESULTS
Boring 98-49
SFOBB East Span Seismic Safety Project

PLATE 98-49.10e

98-49		IDENTIFICATION TESTS						STRENGTH ESTIMATE			MINIATURE VANE TESTS			REMOTE VANE (kPa)	UU TRIAXIAL			MULTI-STAGE TRIAXIAL		DIRECT SHEAR TESTS				ADDITIONAL TESTS	MAX DEN (kN/m3)	MIN DEN (kN/m3)
DEPTH (m)	Sample No.	MC (%)	LL (%)	PL (%)	LI	SUW (kN/m3)	Fines (%)	Torvane (kPa)	Pocket Pen. (kPa)	Fall Cone (kPa)	Undist. (kPa)	Remold. (kPa)	Resid. (kPa)		Undist. (kPa)	Remold. (kPa)	e50 (%)	c (kPa)	phi (deg)	Peak c (kPa)	Peak phi (deg)	Post Peak c (kPa)	Post Peak phi (deg)			
63.3	70	38	58	27	0.37																			C		
63.4	71	45	64	31	0.42																					
66.8	72	46	65	29	0.47										203.5	82.7	1.0									
66.9	73	46	74	38	0.22	7.4			215.5						232.2		1.2									
67.1	74								201.1																	
70.6	76	26	40	18	0.37				201.1						253.3	79.6	1.0									
70.7	77					9.7			201.1																	
74.2	79	28	48	23	0.22	9.4									187.5		4.2									
74.4	80								191.5																	
77.7	81	30	56	22	0.24										210.1	94.2	1.8									
77.9	82					9.1																				
78.0	83								196.3																	
78.5	84	32	58	20	0.32				196.3															C		
78.6	85	29																								
82.1	87	24				9.9	27											0.0	33							

Identification Tests
MC = Moisture Content
LL = Liquid Limit
PL = Plastic Limit
LI = Liquidity Index

Identification Tests
SUW = Submerged Unit Weight
Fines = % Passing No. 200 Sieve

Strength Tests
UU = Unconsolidated Undrained
e50 = Strain at 50% Failure Stress
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Additional Tests
H = Hydrometer
C = Consolidation Test
RC = Resonant Column
CS = Cyclic Simple Shear

Additional Tests
K = Ko Consolidated Triaxial Test

SUMMARY OF LABORATORY TEST RESULTS
Boring 98-49
SFOBB East Span Seismic Safety Project

98-49		IDENTIFICATION TESTS						STRENGTH ESTIMATE			MINIATURE VANE TESTS			REMOTE VANE (kPa)	UU TRIAXIAL			MULTI-STAGE TRIAXIAL		DIRECT SHEAR TESTS				ADDITIONAL TESTS	MAX DEN (kN/m3)	MIN DEN (kN/m3)
DEPTH (m)	Sample No.	MC (%)	LL (%)	PL (%)	LI	SUW (kN/m3)	Fines (%)	Torvane (kPa)	Pocket Pen. (kPa)	Fall Cone (kPa)	Undist. (kPa)	Remold. (kPa)	Resid. (kPa)		Undist. (kPa)	Remold. (kPa)	e50 (%)	c (kPa)	phi (deg)	Peak c (kPa)	Peak phi (deg)	Post Peak c (kPa)	Post Peak phi (deg)			
82.3	88	24					7																			
84.0	89	24				9.5	21																			
86.1	90	16				11.5	48																			
86.3	91	31	46	18	0.45		87																			
88.2	92	16					6																			
90.3	93						5																			
92.4	94						8																			
94.0	95	12					7																			
95.5	96	17					12																			

Identification Tests
MC = Moisture Content
LL = Liquid Limit
PL = Plastic Limit
LI = Liquidity Index

Identification Tests
SUW = Submerged Unit Weight
Fines = % Passing No. 200 Sieve

Strength Tests
UU = Unconsolidated Undrained
e50 = Strain at 50% Failure Stress
c = Effective Cohesion
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Additional Tests
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RC = Resonant Column
CS = Cyclic Simple Shear

Additional Tests
K = Ko Consolidated Triaxial Test

SUMMARY OF LABORATORY TEST RESULTS
Boring 98-49
SFOBB East Span Seismic Safety Project

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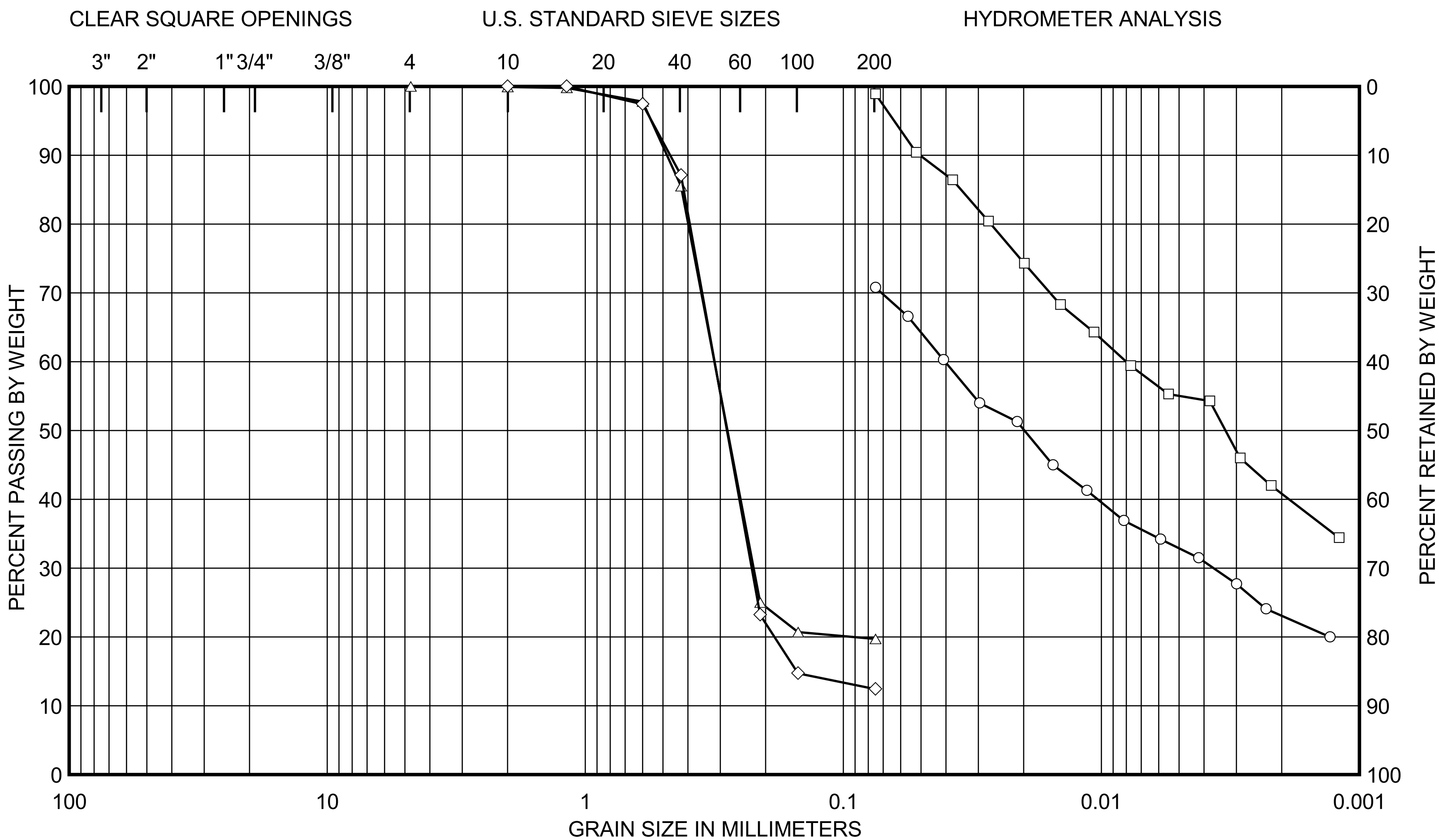
SFOBB Task Order No. 5
Project No. 98-42-0054



	GRAVEL		SAND			SILT (nonplastic)
	COARSE	FINE	COARSE	MEDIUM	FINE	to CLAY (plastic)

SAMPLE NO.	DEPTH (m)	CURVE	CLASSIFICATION	Cc	Cu	D50 (mm)
5	1.4	○—○	FAT CLAY (CH) with sand, silt pockets and shell fragments			0.020
8	2.3	□—□	FAT CLAY (CH)			0.0033
16	5.8	△—△	SILTY FINE SAND (SM) with a trace of medium sand			0.28
25	8.4	◇—◇	SILTY FINE SAND (SM) with a few clay pockets and a trace of medium sand			0.28

PLATE 98-49.11a

GRAIN SIZE DISTRIBUTION CURVES

Boring 98-49

SFOBB East Span Seismic Safety Project

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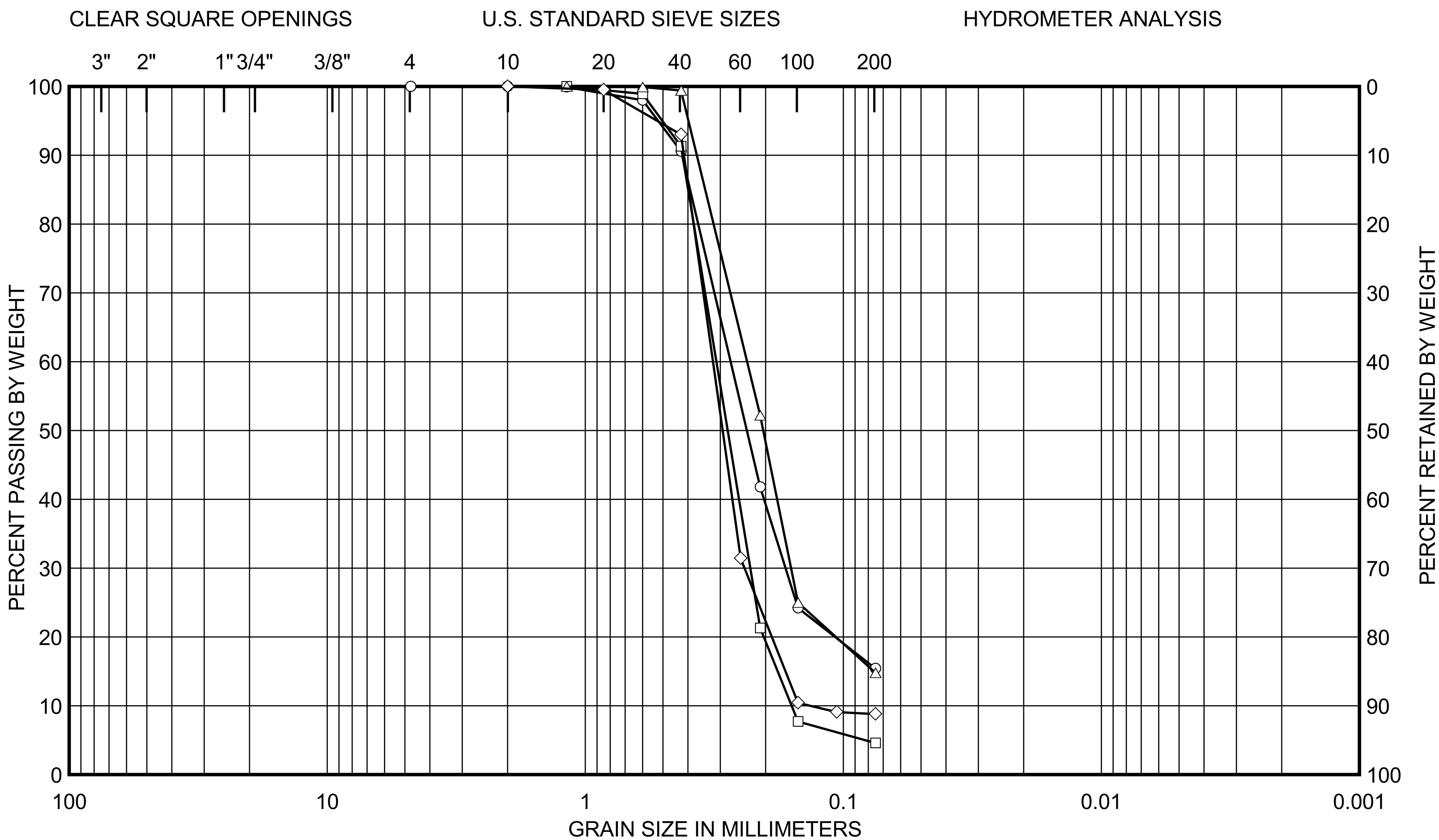
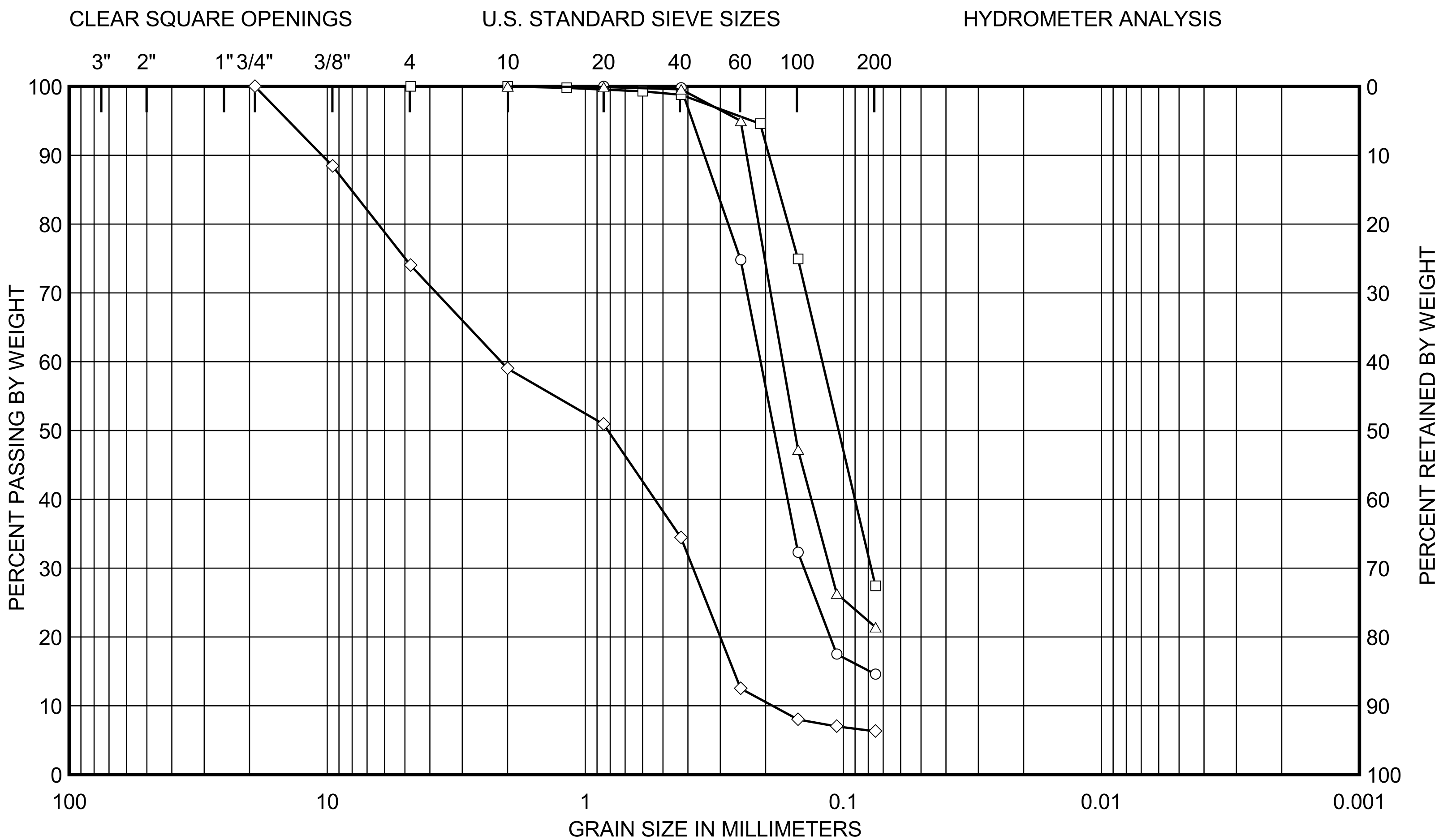


	GRAVEL		SAND			SILT (nonplastic) to CLAY (plastic)
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	DEPTH (m)	CURVE	CLASSIFICATION	Cc	Cu	D50 (mm)
27	9.3	○——○	SILTY FINE SAND (SM) with a trace of medium sand			0.24
32	13.1	□——□	FINE SAND (SP) with a trace of medium sand	1.1	2.0	0.28
51	34.6	△——△	SILTY FINE SAND (SM) with clay pockets, partings and seams			0.20
53	38.3	◇——◇	FINE SAND (SP-SM) with silt and a trace of medium sand	1.4	2.4	0.29

GRAIN SIZE DISTRIBUTION CURVES
Boring 98-49
SFOBB East Span Seismic Safety Project



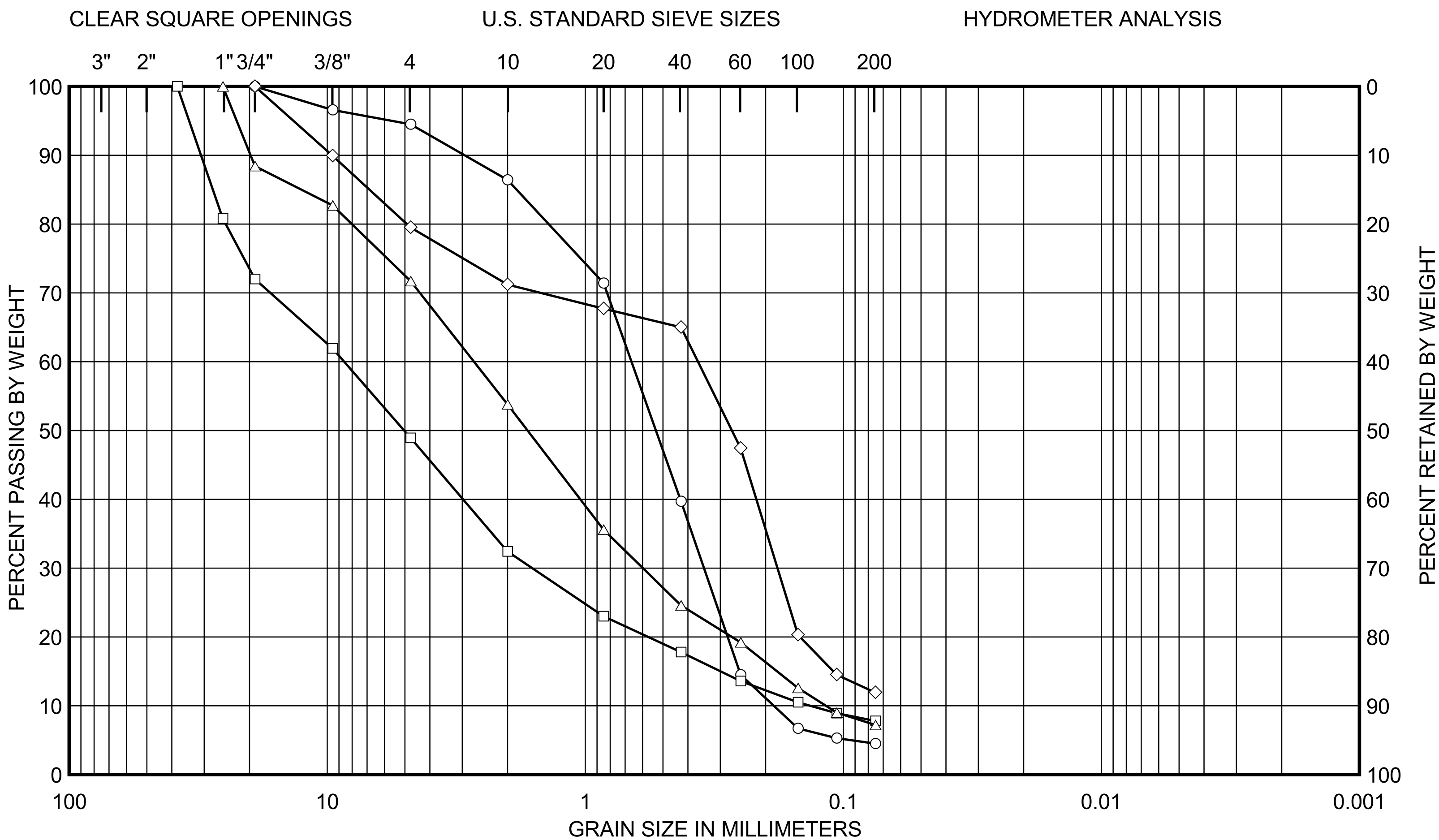
GRAVEL		SAND			SILT (nonplastic) to CLAY (plastic)
COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	DEPTH (m)	CURVE	CLASSIFICATION	Cc	Cu	D50 (mm)
63	55.0	○—○	SILTY FINE SAND (SM)			0.19
87	82.1	□—□	SILTY FINE SAND (SM)			0.10
89	84.0	△—△	SILTY FINE SAND (SM)			0.15
92	88.2	◇—◇	FINE TO COARSE SAND (SP-SM) with silt and gravel	0.4	11.3	0.82

GRAIN SIZE DISTRIBUTION CURVES
Boring 98-49
SFOBB East Span Seismic Safety Project

i:\caltrans\98-49 04/44/YY

SFOBB Task Order No. 5
Project No. 98-42-0054



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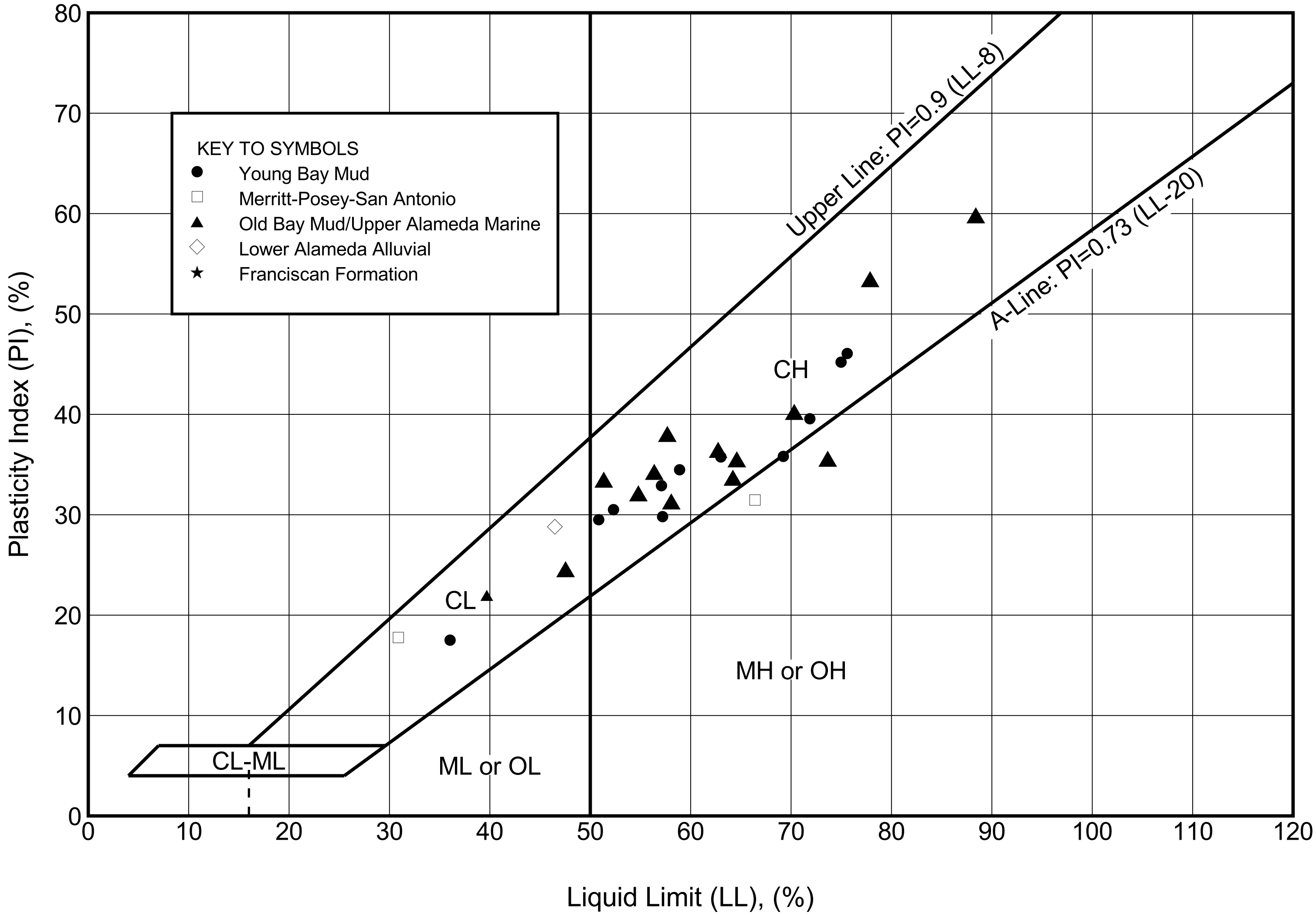
<tr><td rowspan="2"></td><td colspan="2">GRAVEL</td><td colspan="3">SAND</td><td>SILT (nonplastic)</td></tr>
<tr><td>COARSE</td><td>FINE</td><td>COARSE</td><td>MEDIUM</td><td>FINE</td><td>to CLAY (plastic)</td></tr>
</table>

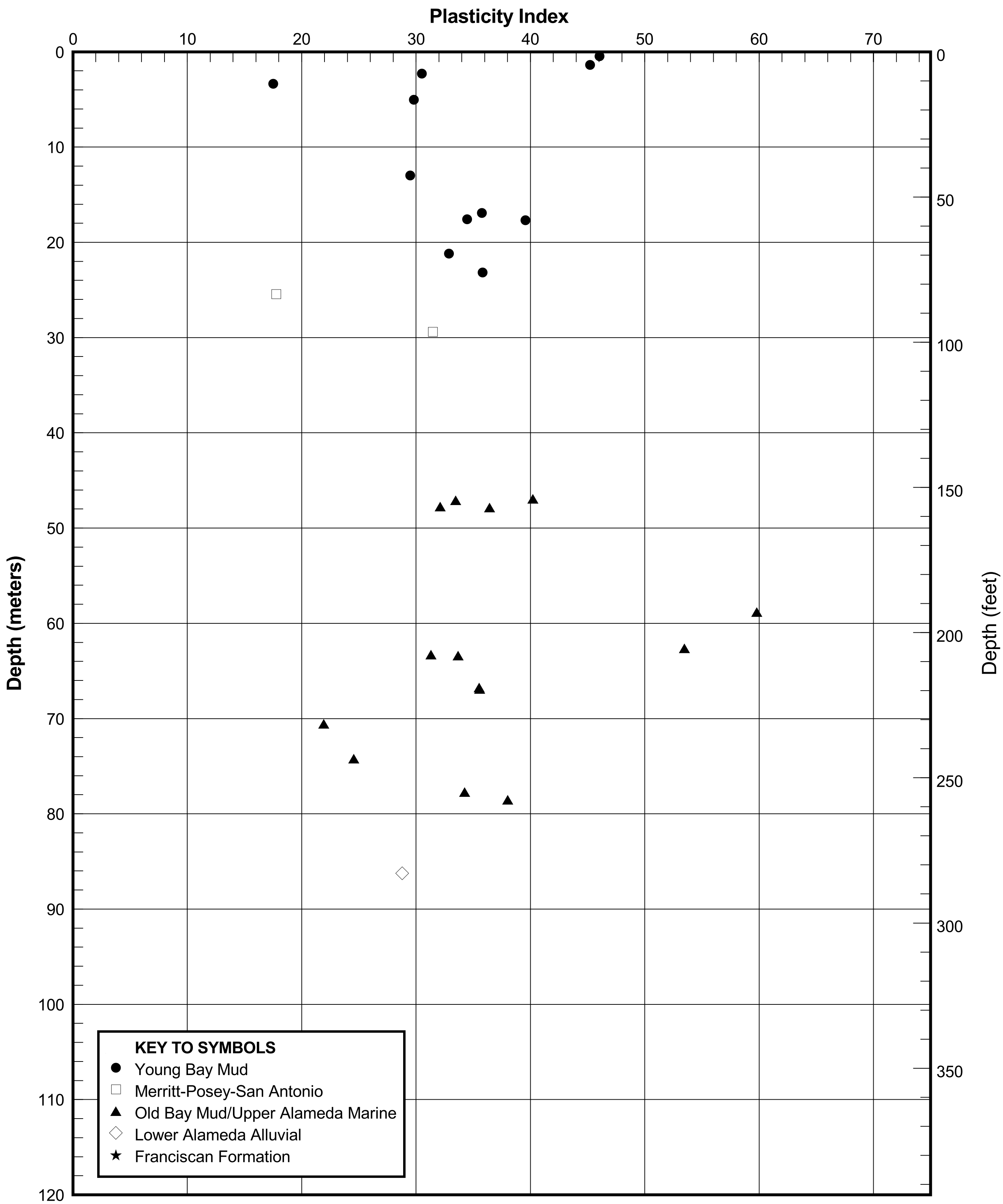
SAMPLE NO.	DEPTH (m)	CURVE	CLASSIFICATION	Cc	Cu	D50 (mm)
93	90.3	○——○	FINE TO MEDIUM SAND (SP) with a trace of coarse sand	1.0	3.6	0.53
94	92.4	□——□	FINE TO COARSE GRAVEL (GW-GM) with silt and sand	2.2	63.9	5.0
95	94.0	△——△	FINE TO COARSE SAND (SW-SM) with silt and fine gravel	1.1	23.1	1.7
96	95.5	◇——◇	FINE SAND (SP-SM) with silt, fine gravel and a trace of coarse sand			0.27

GRAIN SIZE DISTRIBUTION CURVES
Boring 98-49
SFOBB East Span Seismic Safety Project

PLATE 98-49.11d

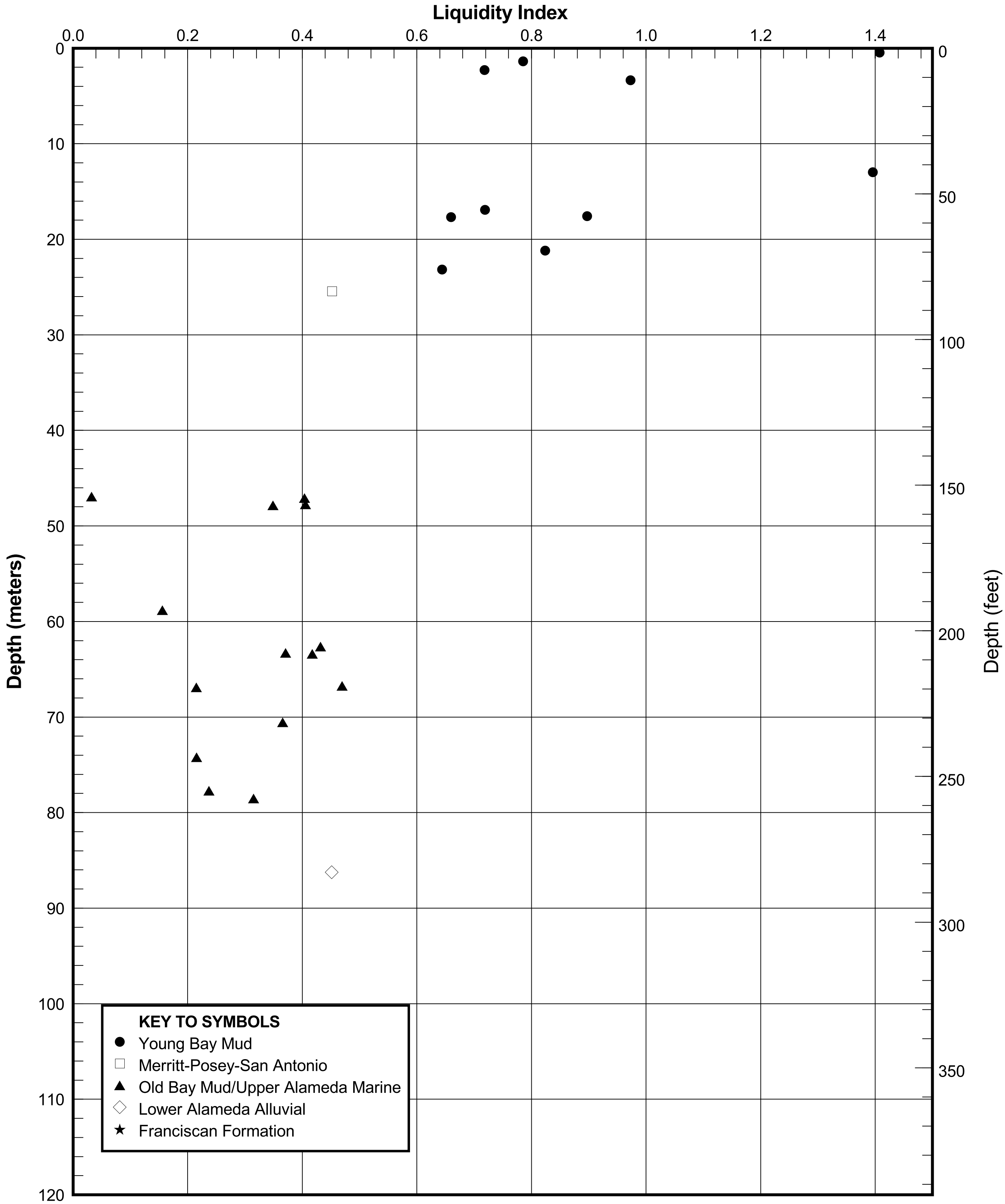


PLASTICITY CHART
Boring 98-49
SFOBB East Span Seismic Safety Project



PLASTICITY INDEX PROFILE
Boring 98-49
SFOBB East Span Seismic Safety Project

SFOBB Task Order No. 5
Project No. 98-42-0054

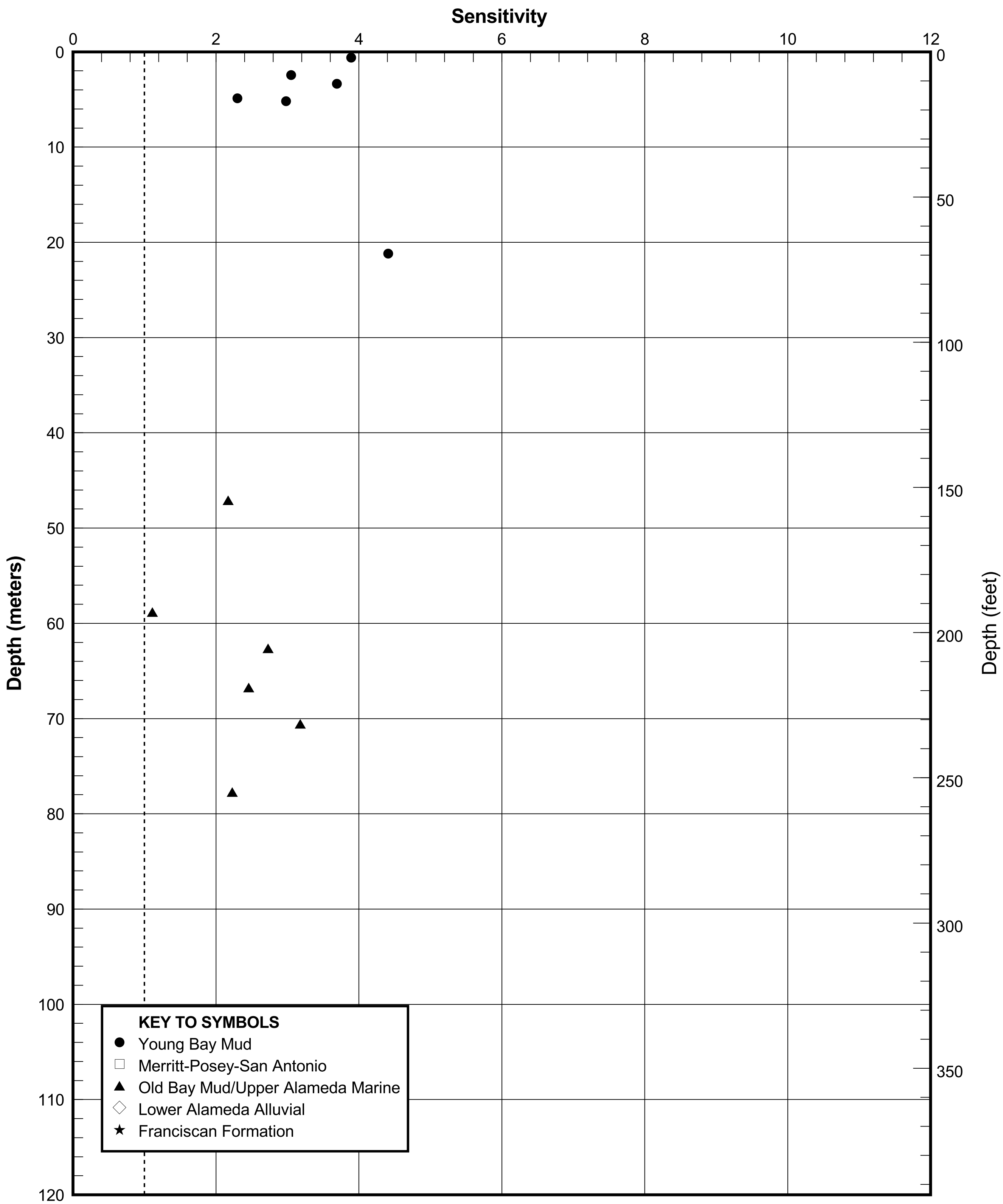


LIQUIDITY INDEX PROFILE
Boring 98-49
SFOBB East Span Seismic Safety Project

PLATE 98-49.18

geol1-7.apr, LabPlots, 04/27/99, CBD

SFOBB Task Order No. 5
Project No. 98-42-0054

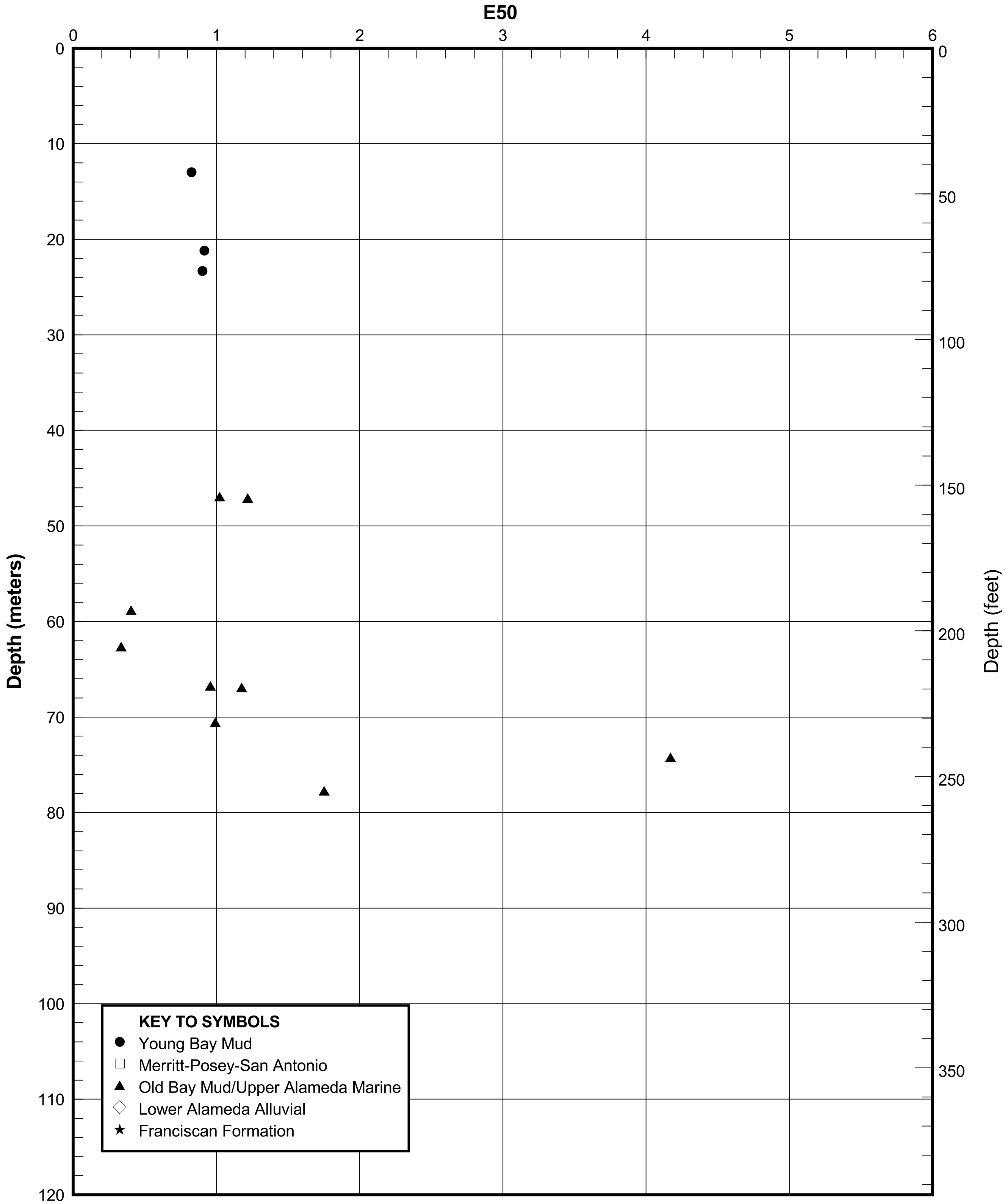


SENSITIVITY PROFILE
Boring 98-49
SFOBB East Span Seismic Safety Project

PLATE 98-49.19

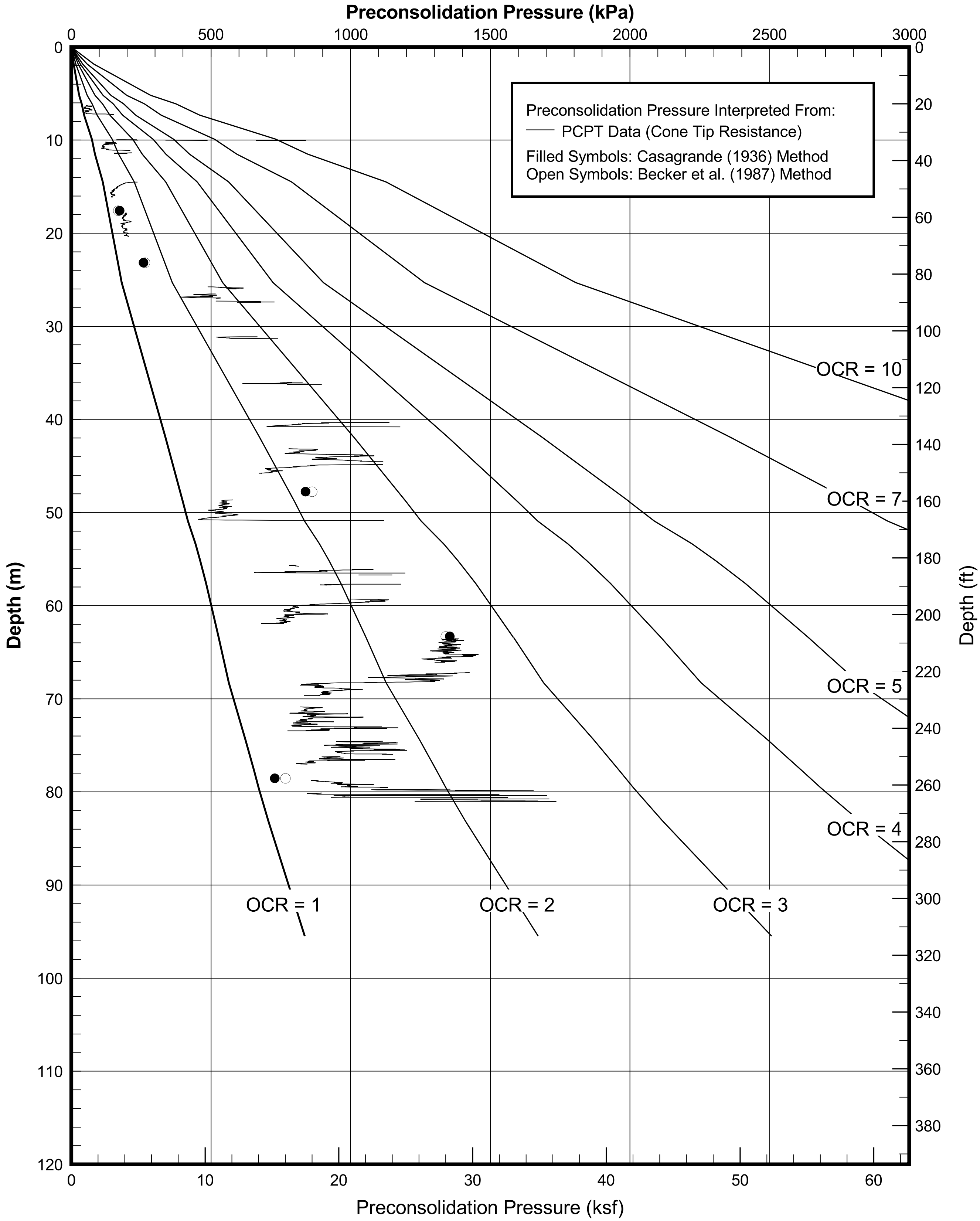
geol1-7.apr, LabPlots, 04/27/99, CBD

SFOBB Task Order No. 5
Project No. 98-42-0054



E50 PROFILE
Boring 98-49
SFOBB East Span Seismic Safety Project

PLATE 98-49.20

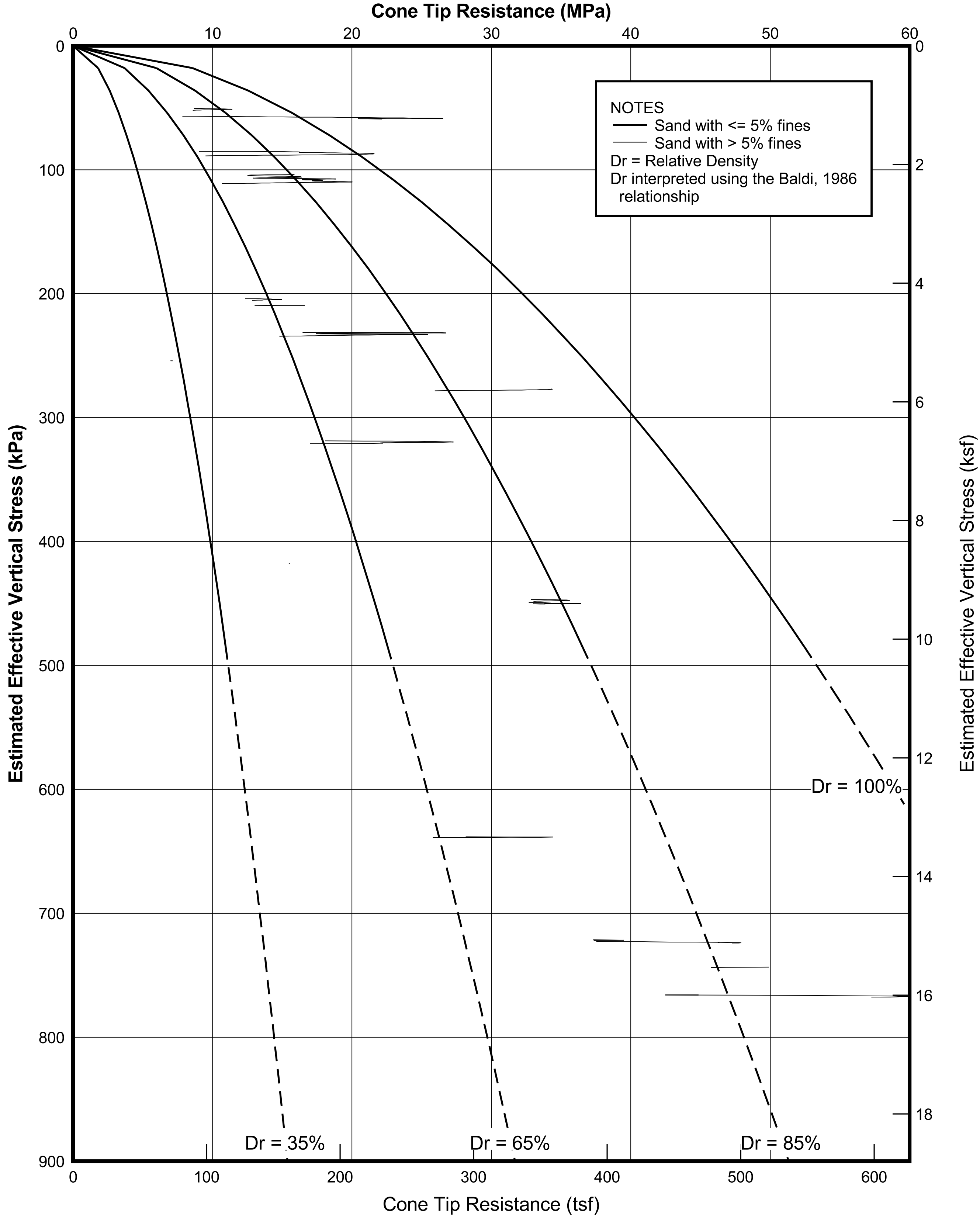


PRECONSOLIDATION PRESSURE INTERPRETED FROM CPT DATA

Boring 98-49

SFOBB East Span Seismic Safety Project

PLATE 98-49.21



RELATIVE DENSITY INTERPRETED FROM CPT DATA

Boring 98-49

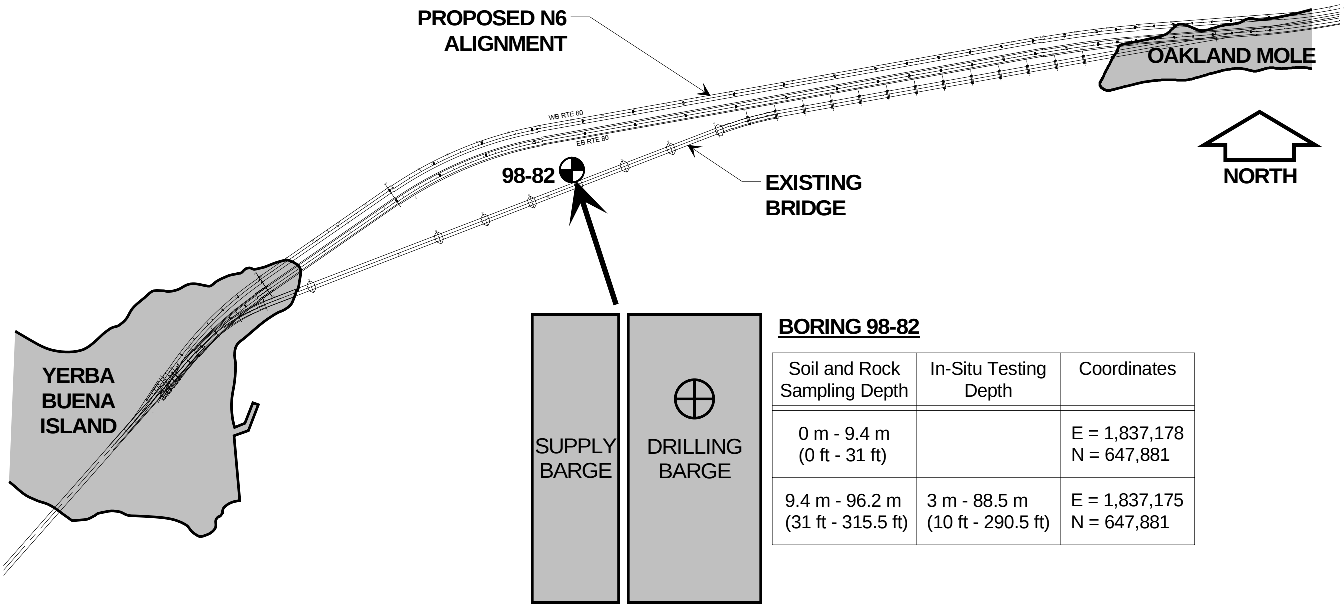
SFOBB East Span Seismic Safety Project

PLATE 98-49.22

BORING 98-82

Date	Time		Description of Activity
	From	To	
November 7, 1998	0215	0430	Move barge to location 98-82. Set 4 anchors and 2 spuds.
	0430	0930	Wait on weather.
	0930	1015	Rig up for drilling. Lower drill pipe to mudline.
	1015	1030	Measure water depth of 10.2m (33.5 ft) using bottom sensor. Current tide level is approximately +0.5m (+1.5 ft) MSL. Calculate mudline elevation of –9.8m (-32.0 ft) MSL.
	1030	1315	Drill and sample from mudline to 9.5m (31 ft).
	1315	2000	Pull drill pipe to deck. Reposition barge. Set casing.
	2000	2045	Drive stinger to 6.1m (20 ft).
	2045	2330	Maintenance on piston and drill bit.
	2330	2400	Drill to 3m (10 ft).
November 8, 1998	0000	2400	Drill, sample, and CPT testing from 3.0m (10 ft) to 89.9m (295 ft).
November 9, 1998	0000	0230	Drill and sample from 89.9m (295 ft) to 96.2m (315.5 ft).
	0230	0315	Pull drill pipe to deck.
	0315	0630	P- and S-wave velocity logging from 89.0m (292 ft) to 7.0m (23 ft).
	0630	0900	Lower N-rod. Mix and circulate cement grout. Grout hole 98-82. Pull N-rod to deck.
	0900	1030	Pull casing to deck.
	1030	1130	Pull 2 spuds, 4 anchors, and move barge to location 98-81.

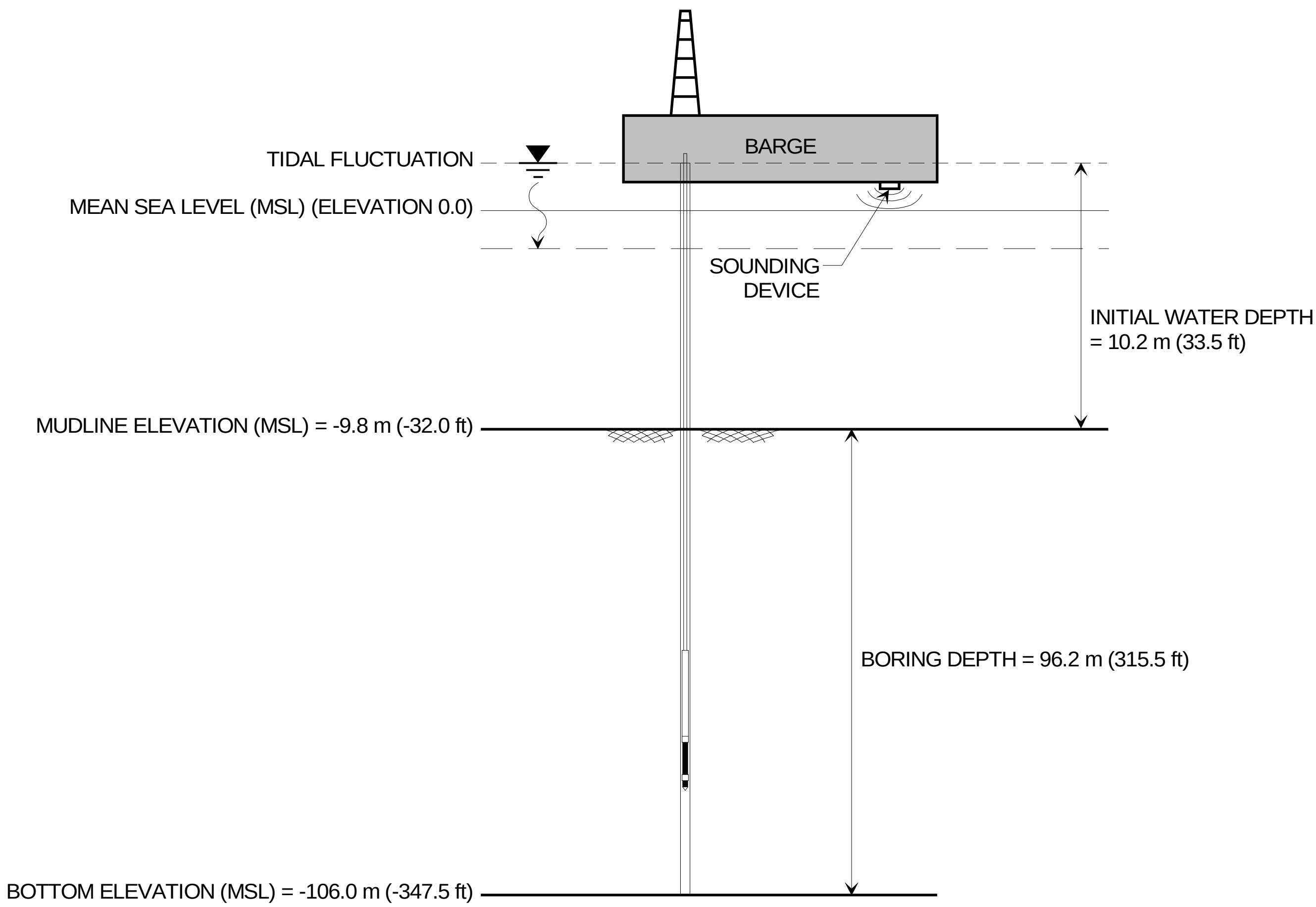
SFOBB Task Order No. 5
Project No. 98-42-0054



BORING 98-82

Soil and Rock Sampling Depth	In-Situ Testing Depth	Coordinates
0 m - 9.4 m (0 ft - 31 ft)		E = 1,837,178 N = 647,881
9.4 m - 96.2 m (31 ft - 315.5 ft)	3 m - 88.5 m (10 ft - 290.5 ft)	E = 1,837,175 N = 647,881

Coordinates in NAD83, CA Zone 3, meters.



98420054loc3.dsf(0.82)

DEPTH AND LOCATION REFERENCE MAP
Boring 98-82
SFOBB East Span Seismic Safety Project

PLATE 98-82.2

98-82		IDENTIFICATION TESTS						STRENGTH ESTIMATE			MINIATURE VANE TESTS			REMOTE VANE (kPa)	UU TRIAXIAL			MULTI-STAGE TRIAXIAL		DIRECT SHEAR TESTS				ADDITIONAL TESTS
DEPTH (m)	Sample No.	MC (%)	LL (%)	PL (%)	LI	SUW (kN/m3)	Fines (%)	Torvane (kPa)	Pocket Pen. (kPa)	Fall Cone (kPa)	Undist. (kPa)	Remold. (kPa)	Resid. (kPa)		Undist. (kPa)	Remold. (kPa)	e50 (%)	c (kPa)	phi (deg)	Peak c (kPa)	Peak phi (deg)	Post Peak c (kPa)	Post Peak phi (deg)	
0.3	1		54	21																				
0.5	2					8.4					3.4													
0.6	3	32	22	14	2.16	7.8	19																	
1.4	5					8.2																		
1.5	6	34				8.8	27																	
2.0	7					9.0	20																	
2.1	8	31																						
2.9	9						15																	
3.0	10	23				9.1																		
4.0	11					7.7				36.4														
4.1	12	37	39	18	0.90	7.8				35.4	22.9													
4.7	13					7.5		32.6																
4.9	14	39	39	18	1.03			29.7		36.4	38.9													
5.6	15	26					4																	
6.7	17	23				9.3	3																	

Identification Tests
MC = Moisture Content
LL = Liquid Limit
PL = Plastic Limit
LI = Liquidity Index

Identification Tests
SUW = Submerged Unit Weight
Fines = % Passing No. 200 Sieve

Strength Tests
UU = Unconsolidated Undrained
e50 = Strain at 50% Failure Stress
c = Effective Cohesion
phi = Effective Angle of Friction

Additional Tests
H = Hydrometer
C = Consolidation Test
RC = Resonant Column
CS = Cyclic Simple Shear

Additional Tests
K = Ko Consolidated Triaxial Test

SUMMARY OF LABORATORY TEST RESULTS
Boring 98-82
SFOBB East Span Seismic Safety Project

98-82		IDENTIFICATION TESTS						STRENGTH ESTIMATE			MINIATURE VANE TESTS			REMOTE VANE (kPa)	UU TRIAXIAL			MULTI-STAGE TRIAXIAL		DIRECT SHEAR TESTS				ADDITIONAL TESTS
DEPTH (m)	Sample No.	MC (%)	LL (%)	PL (%)	LI	SUW (kN/m3)	Fines (%)	Torvane (kPa)	Pocket Pen. (kPa)	Fall Cone (kPa)	Undist. (kPa)	Remold. (kPa)	Resid. (kPa)		Undist. (kPa)	Remold. (kPa)	e50 (%)	c (kPa)	phi (deg)	Peak c (kPa)	Peak phi (deg)	Post Peak c (kPa)	Post Peak phi (deg)	
7.5	18						14																	
7.6	19	20				11.1																		
8.5	20	42	63	25	0.44	7.7		77.6								26.7								
8.6	21									84.3	92.6													
9.4	23	44	37	15	1.32	8.5																		
9.6	24		34	26			92																	
12.5	25						23																	
12.6	26	22				10.4																		
16.2	27							100.5	95.8															
16.3	28	50	73	23	0.54	6.1	99								109.1	25.9	0.8							H
16.5	29							102.9	110.1	132.1	170.8													
17.0	30	48	68	21	0.57																			C
17.1	31										120.0													
20.4	32							114.9	114.9	127.4														
20.6	33					7.1																		

Identification Tests
MC = Moisture Content
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Identification Tests
SUW = Submerged Unit Weight
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UU = Unconsolidated Undrained
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SUMMARY OF LABORATORY TEST RESULTS
Boring 98-82
SFOBB East Span Seismic Safety Project

98-82		IDENTIFICATION TESTS						STRENGTH ESTIMATE			MINIATURE VANE TESTS			REMOTE VANE (kPa)	UU TRIAXIAL			MULTI-STAGE TRIAXIAL		DIRECT SHEAR TESTS				ADDITIONAL TESTS
DEPTH (m)	Sample No.	MC (%)	LL (%)	PL (%)	LI	SUW (kN/m3)	Fines (%)	Torvane (kPa)	Pocket Pen. (kPa)	Fall Cone (kPa)	Undist. (kPa)	Remold. (kPa)	Resid. (kPa)		Undist. (kPa)	Remold. (kPa)	e50 (%)	c (kPa)	phi (deg)	Peak c (kPa)	Peak phi (deg)	Post Peak c (kPa)	Post Peak phi (deg)	
20.7	34	48	61	19	0.68					173.3	172.0													
21.6	400													161.4										
22.3	401													159.0										
23.2	35							117.3	134.1	159.9														
23.3	36	41	59	19	0.54	7.6									123.0		1.3							
23.5	37								134.1	173.3	180.7													
28.2	39					8.7																		
28.3	40	36	35	16	1.07		38			87.1	144.8													
32.3	41								124.5															
32.5	42	34	51	20	0.45	8.3	90								146.0	30.9	1.0							H
32.6	43									173.3	157.2													
33.1	44	39	51	22	0.57																			C
33.2	45	38	57	23	0.45						137.4													
37.8	46								172.4															
37.9	47	42	74	28	0.31	7.6									132.5		0.4							

Identification Tests
MC = Moisture Content
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LI = Liquidity Index

Identification Tests
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SUMMARY OF LABORATORY TEST RESULTS
Boring 98-82
SFOBB East Span Seismic Safety Project

98-82		IDENTIFICATION TESTS						STRENGTH ESTIMATE			MINIATURE VANE TESTS			REMOTE VANE (kPa)	UU TRIAXIAL			MULTI-STAGE TRIAXIAL		DIRECT SHEAR TESTS				ADDITIONAL TESTS
DEPTH (m)	Sample No.	MC (%)	LL (%)	PL (%)	LI	SUW (kN/m3)	Fines (%)	Torvane (kPa)	Pocket Pen. (kPa)	Fall Cone (kPa)	Undist. (kPa)	Remold. (kPa)	Resid. (kPa)		Undist. (kPa)	Remold. (kPa)	e50 (%)	c (kPa)	phi (deg)	Peak c (kPa)	Peak phi (deg)	Post Peak c (kPa)	Post Peak phi (deg)	
38.1	48							148.4			205.5													
42.7	49	36	58	25	0.31			119.7	124.5						180.4		1.0							
42.8	50	38	61	24	0.38	7.9									155.9	39.7	0.9							
43.0	51						15	124.5	129.3	159.9	167.1													
47.4	52					8.6		167.6	177.2															
47.9	54	39	45	17	0.79		60				149.8													
52.4	55	42	76	28	0.29			143.6	167.6						204.2		0.9							
52.6	56	55	87	26	0.47	7.1	99								180.0		0.8							H
52.7	57										173.3													
53.2	58	15	18	10	0.59																			C
53.3	59	16	21	12	0.49																			
57.8	60	26	31	17	0.61	9.8			196.3															
58.2	62	23	25	20	0.69		45																	
60.5	63					9.9																		
60.6	64						24																	H

Identification Tests
MC = Moisture Content
LL = Liquid Limit
PL = Plastic Limit
LI = Liquidity Index

Identification Tests
SUW = Submerged Unit Weight
Fines = % Passing No. 200 Sieve

Strength Tests
UU = Unconsolidated Undrained
e50 = Strain at 50% Failure Stress
c = Effective Cohesion
phi = Effective Angle of Friction

Additional Tests
H = Hydrometer
C = Consolidation Test
RC = Resonant Column
CS = Cyclic Simple Shear

Additional Tests
K = Ko Consolidated Triaxial Test

SUMMARY OF LABORATORY TEST RESULTS
Boring 98-82
SFOBB East Span Seismic Safety Project

98-82		IDENTIFICATION TESTS						STRENGTH ESTIMATE			MINIATURE VANE TESTS			REMOTE VANE (kPa)	UU TRIAXIAL			MULTI-STAGE TRIAXIAL		DIRECT SHEAR TESTS				ADDITIONAL TESTS
DEPTH (m)	Sample No.	MC (%)	LL (%)	PL (%)	LI	SUW (kN/m3)	Fines (%)	Torvane (kPa)	Pocket Pen. (kPa)	Fall Cone (kPa)	Undist. (kPa)	Remold. (kPa)	Resid. (kPa)		Undist. (kPa)	Remold. (kPa)	e50 (%)	c (kPa)	phi (deg)	Peak c (kPa)	Peak phi (deg)	Post Peak c (kPa)	Post Peak phi (deg)	
63.6	65					10.4	3																	
68.7	66	21				8.6	21																	
73.3	67	29	48	18	0.36	9.2				236.5														
74.3	68	34	59	24	0.28																			C
74.4	69	67	90	32	0.59						222.8													
78.8	70					10.6																		
78.9	71	23					13																	
81.7	72							208.3	251.2															
81.8	73	24	38	16	0.35	10.2									196.2	107.6	0.9							
82.0	74								215.5		222.8													
84.3	75	26				9.3	31																	H
85.7	76						30																	
85.9	77	22				9.5	4																	
87.3	78						7																	
90.1	79						1																	

Identification Tests
MC = Moisture Content
LL = Liquid Limit
PL = Plastic Limit
LI = Liquidity Index

Identification Tests
SUW = Submerged Unit Weight
Fines = % Passing No. 200 Sieve

Strength Tests
UU = Unconsolidated Undrained
e50 = Strain at 50% Failure Stress
c = Effective Cohesion
phi = Effective Angle of Friction

Additional Tests
H = Hydrometer
C = Consolidation Test
RC = Resonant Column
CS = Cyclic Simple Shear

Additional Tests
K = Ko Consolidated Triaxial Test

SUMMARY OF LABORATORY TEST RESULTS
Boring 98-82
SFOBB East Span Seismic Safety Project

98-82		IDENTIFICATION TESTS						STRENGTH ESTIMATE			MINIATURE VANE TESTS			REMOTE VANE (kPa)	UU TRIAXIAL			MULTI-STAGE TRIAXIAL		DIRECT SHEAR TESTS				ADDITIONAL TESTS
DEPTH (m)	Sample No.	MC (%)	LL (%)	PL (%)	LI	SUW (kN/m3)	Fines (%)	Torvane (kPa)	Pocket Pen. (kPa)	Fall Cone (kPa)	Undist. (kPa)	Remold. (kPa)	Resid. (kPa)		Undist. (kPa)	Remold. (kPa)	e50 (%)	c (kPa)	phi (deg)	Peak c (kPa)	Peak phi (deg)	Post Peak c (kPa)	Post Peak phi (deg)	
92.0	80	21					23																	
96.2	81						10																	

Identification Tests
MC = Moisture Content
LL = Liquid Limit
PL = Plastic Limit
LI = Liquidity Index

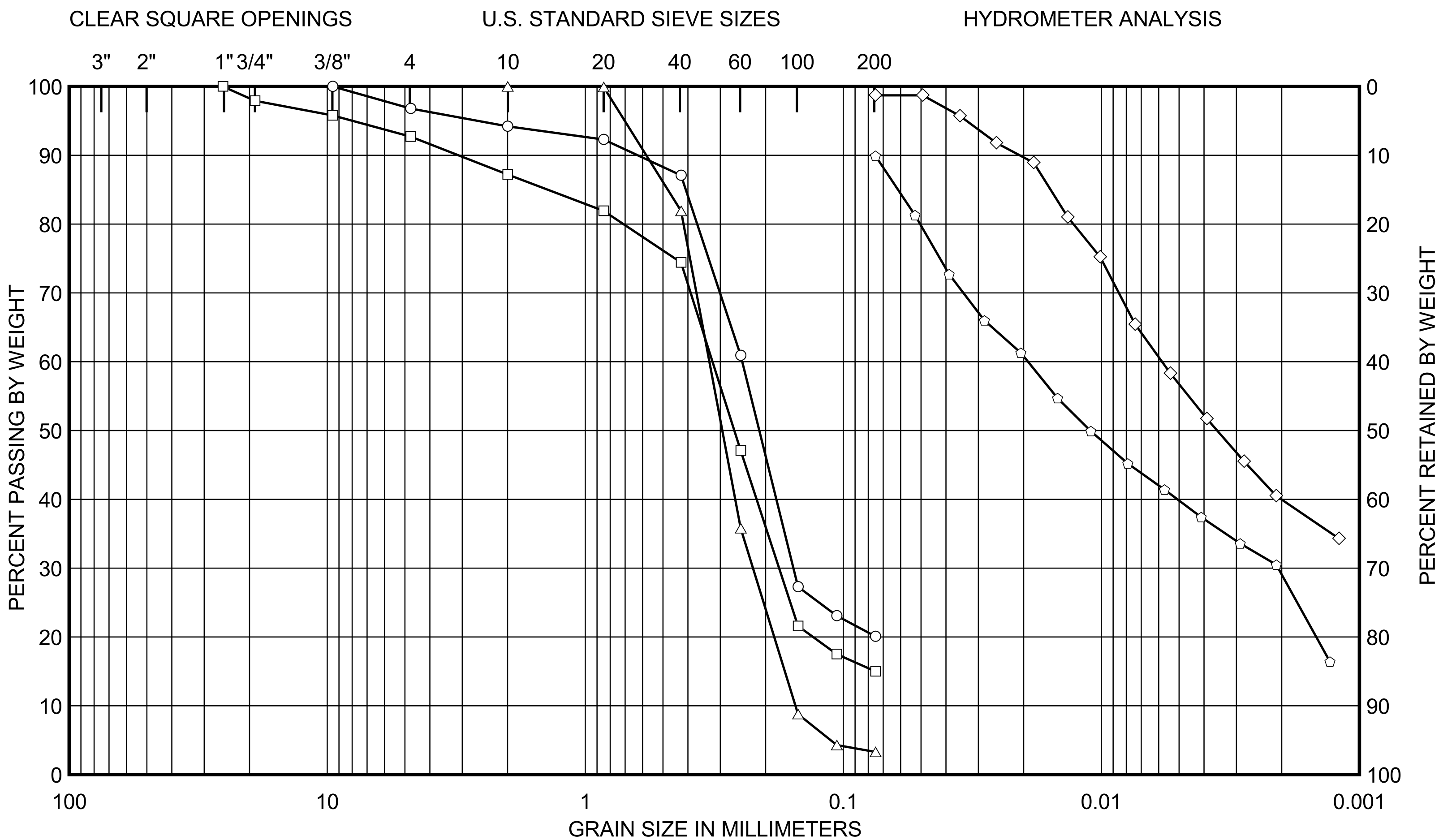
Identification Tests
SUW = Submerged Unit Weight
Fines = % Passing No. 200 Sieve

Strength Tests
UU = Unconsolidated Undrained
e50 = Strain at 50% Failure Stress
c = Effective Cohesion
phi = Effective Angle of Friction

Additional Tests
H = Hydrometer
C = Consolidation Test
RC = Resonant Column
CS = Cyclic Simple Shear

Additional Tests
K = Ko Consolidated Triaxial Test

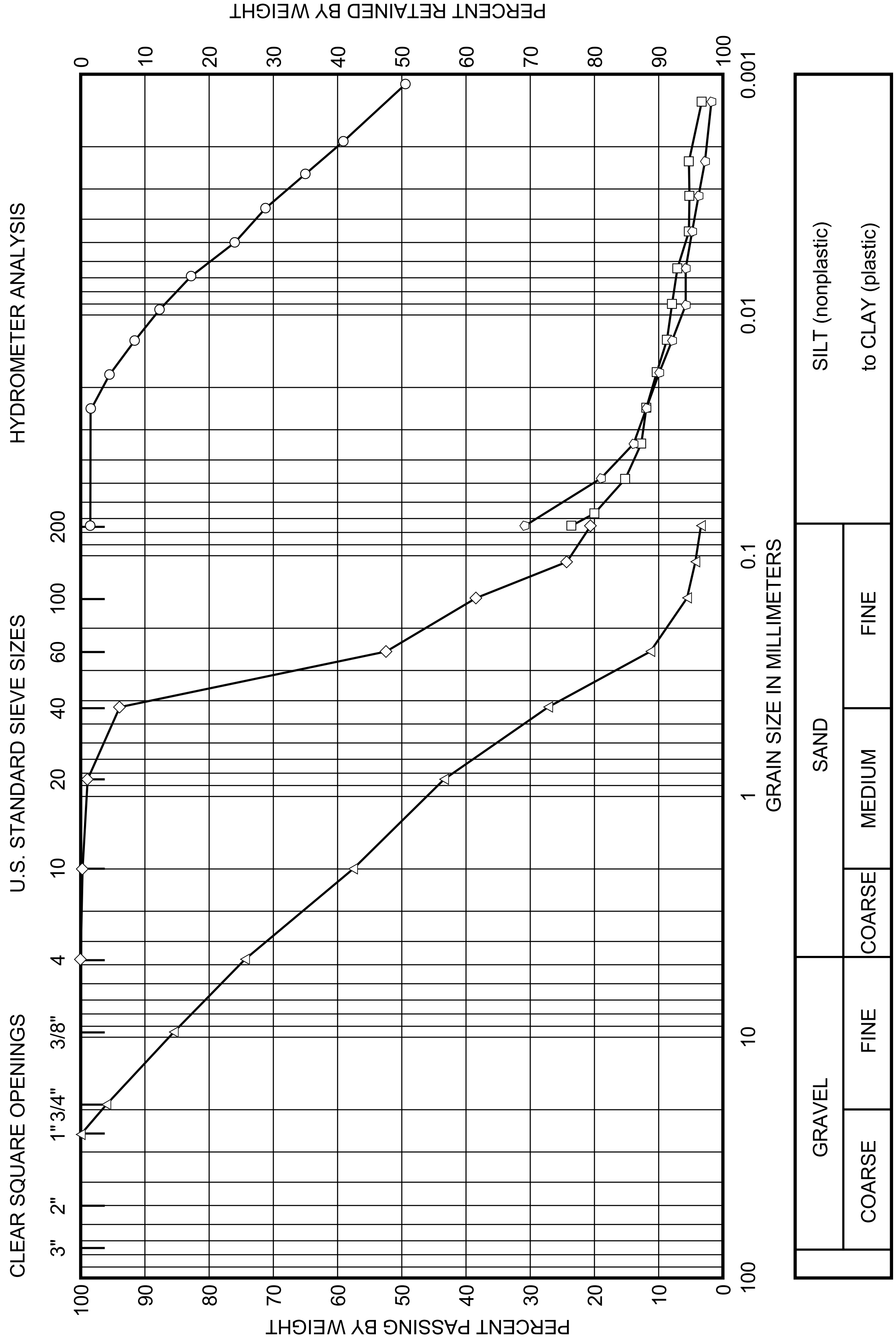
SUMMARY OF LABORATORY TEST RESULTS
Boring 98-82
SFOBB East Span Seismic Safety Project



GRAVEL		SAND			SILT (nonplastic) to CLAY (plastic)
COARSE	FINE	COARSE	MEDIUM	FINE	

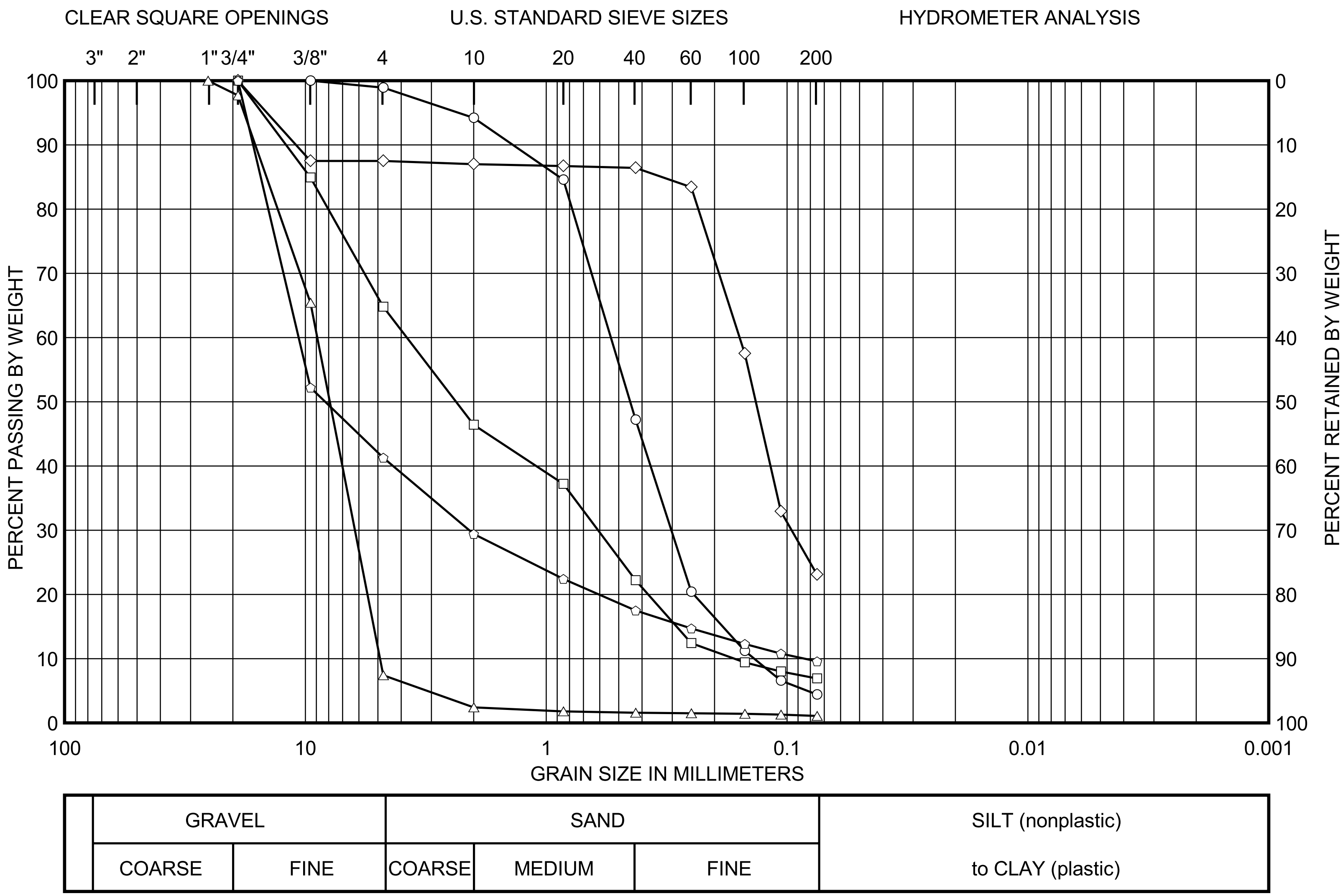
SAMPLE NO.	DEPTH (m)	CURVE	CLASSIFICATION	Cc	Cu	D50 (mm)
7	2.0	○—○	SILTY FINE SAND (SM) with shells, shell fragments and sand pockets			0.21
9	2.9	□—□	SILTY FINE SAND (SM) with shells, shell fragments and sand pockets			0.26
17	6.7	△—△	FINE SAND (SP) with medium sand and clay seams	1.0	2.2	0.29
28	16.3	◇—◇	FAT CLAY (CH)			0.0036
42	32.5	⬠—⬠	FAT CLAY (CH) with a few silt and organic pockets			0.011

GRAIN SIZE DISTRIBUTION CURVES
Boring 98-82
SFOBB East Span Seismic Safety Project



SAMPLE NO.	DEPTH (m)	CURVE	CLASSIFICATION	Cc	Cu	D50 (mm)
56	52.6		FAT CLAY (CH) with many organic pockets and partings			0.0011
64	60.6		SILTY FINE SAND (SM) with clay layers			
65	63.6		FINE TO MEDIUM SAND (SP) with coarse sand and fine gravel	0.5	10.2	1.3
66	68.7		SILTY FINE SAND (SM) with a trace of medium sand			0.23
75	84.3		SILTY FINE SAND (SM)			

GRAIN SIZE DISTRIBUTION CURVES
Boring 98-82
SFOBB East Span Seismic Safety Project

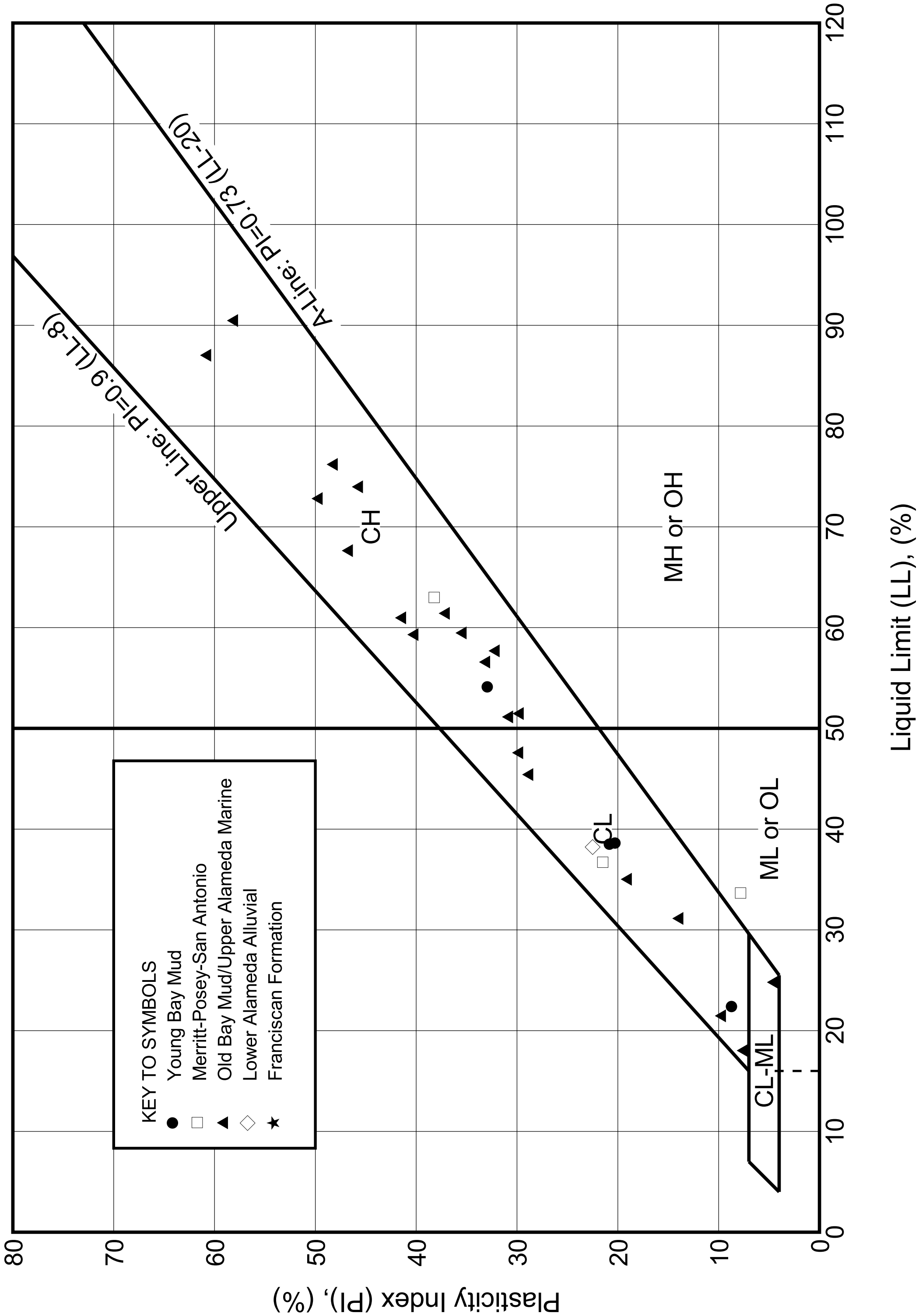


SAMPLE NO.	DEPTH (m)	CURVE	CLASSIFICATION	Cc	Cu	D50 (mm)
77	85.7	○—○	FINE TO MEDIUM SAND (SP) with a trace of coarse sand	1.2	3.9	0.45
78	87.3	□—□	FINE TO COARSE SAND (SP-SM) with silt and fine gravel	0.6	22.8	2.4
79	90.1	△—△	FINE GRAVEL (GP)	0.9	1.8	7.9
80	92.0	◇—◇	SILTY FINE SAND (SM) with fine gravel			0.13
81	96.2	⬠—⬠	FINE GRAVEL (GP-GM) with silt and sand	4.9	126.7	8.3

GRAIN SIZE DISTRIBUTION CURVES

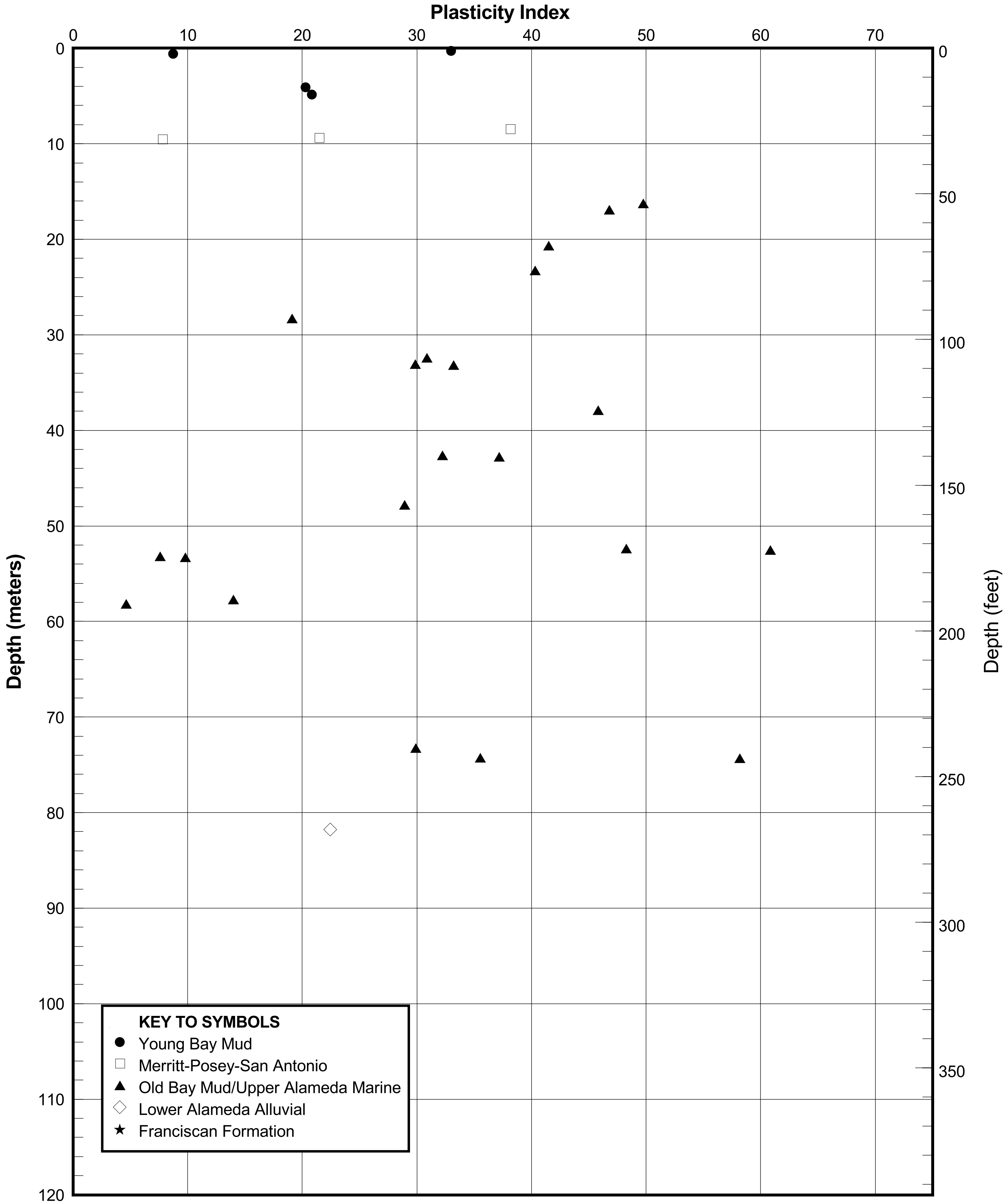
Boring 98-82

SFOBB East Span Seismic Safety Project



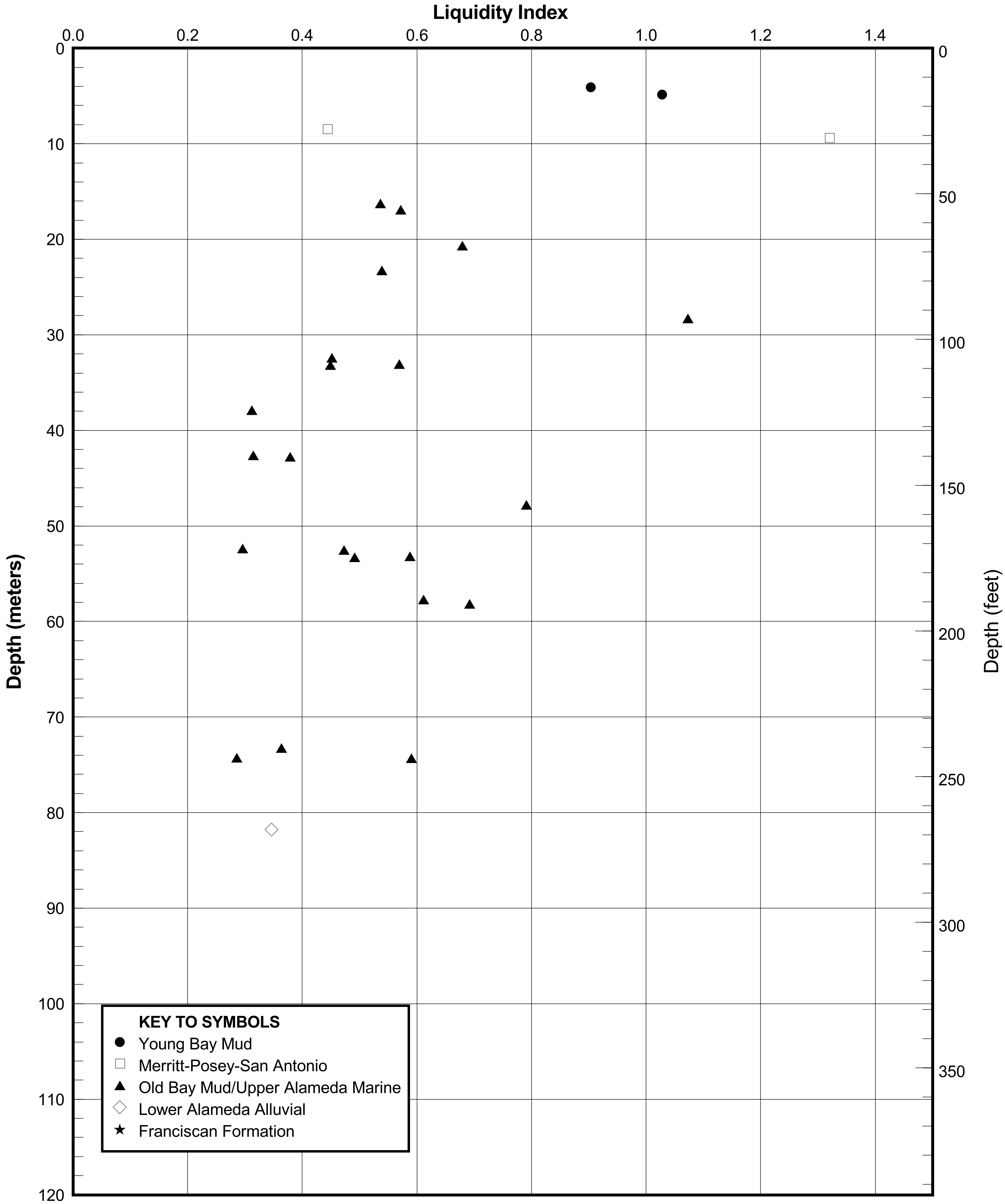
PLASTICITY CHART
Boring 98-82
SFOBB East Span Seismic Safety Project

SFOBB Task Order No. 5
Project No. 98-42-0054

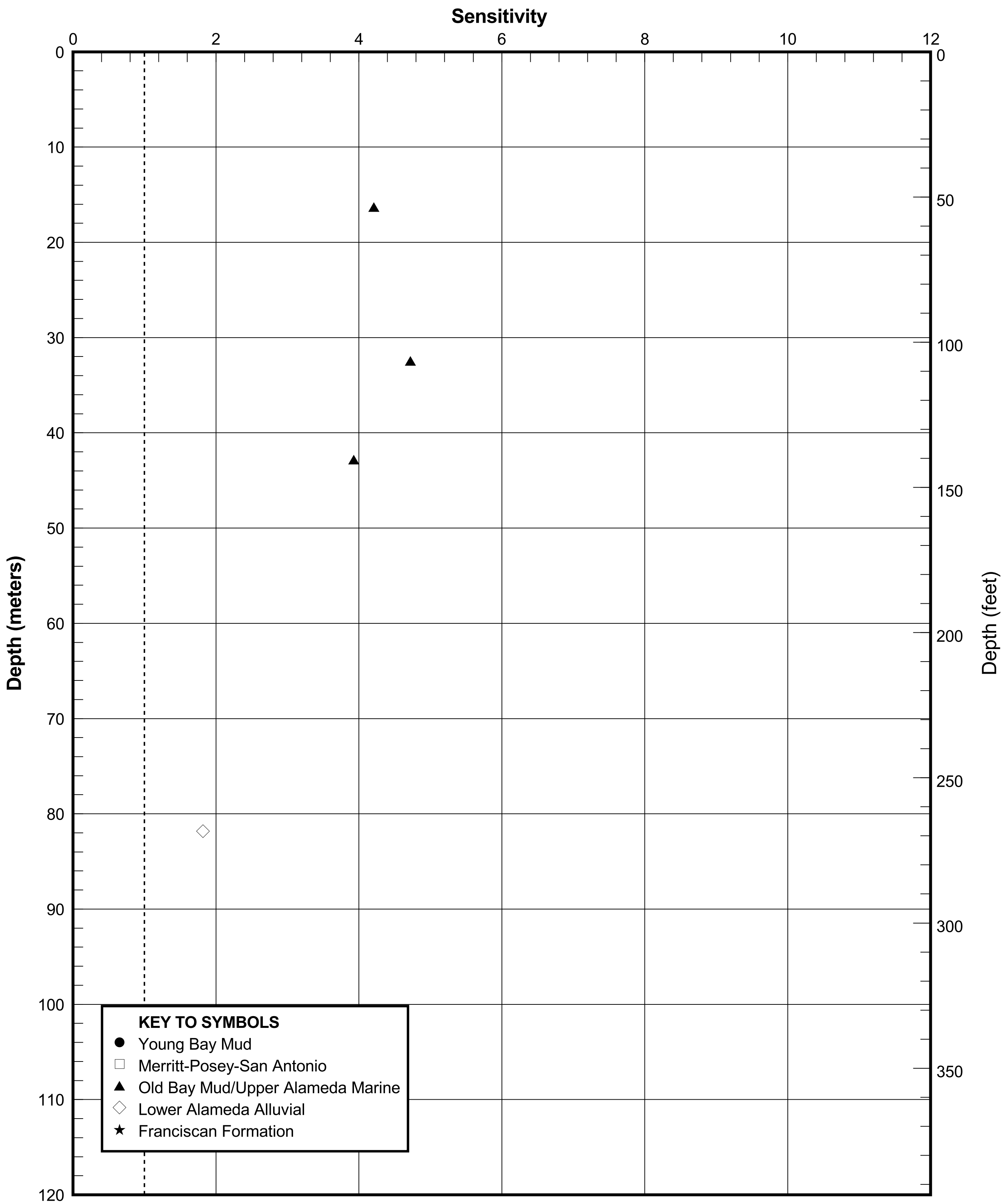


LIQUIDITY INDEX PROFILE
Boring 98-82
SFOBB East Span Seismic Safety Project

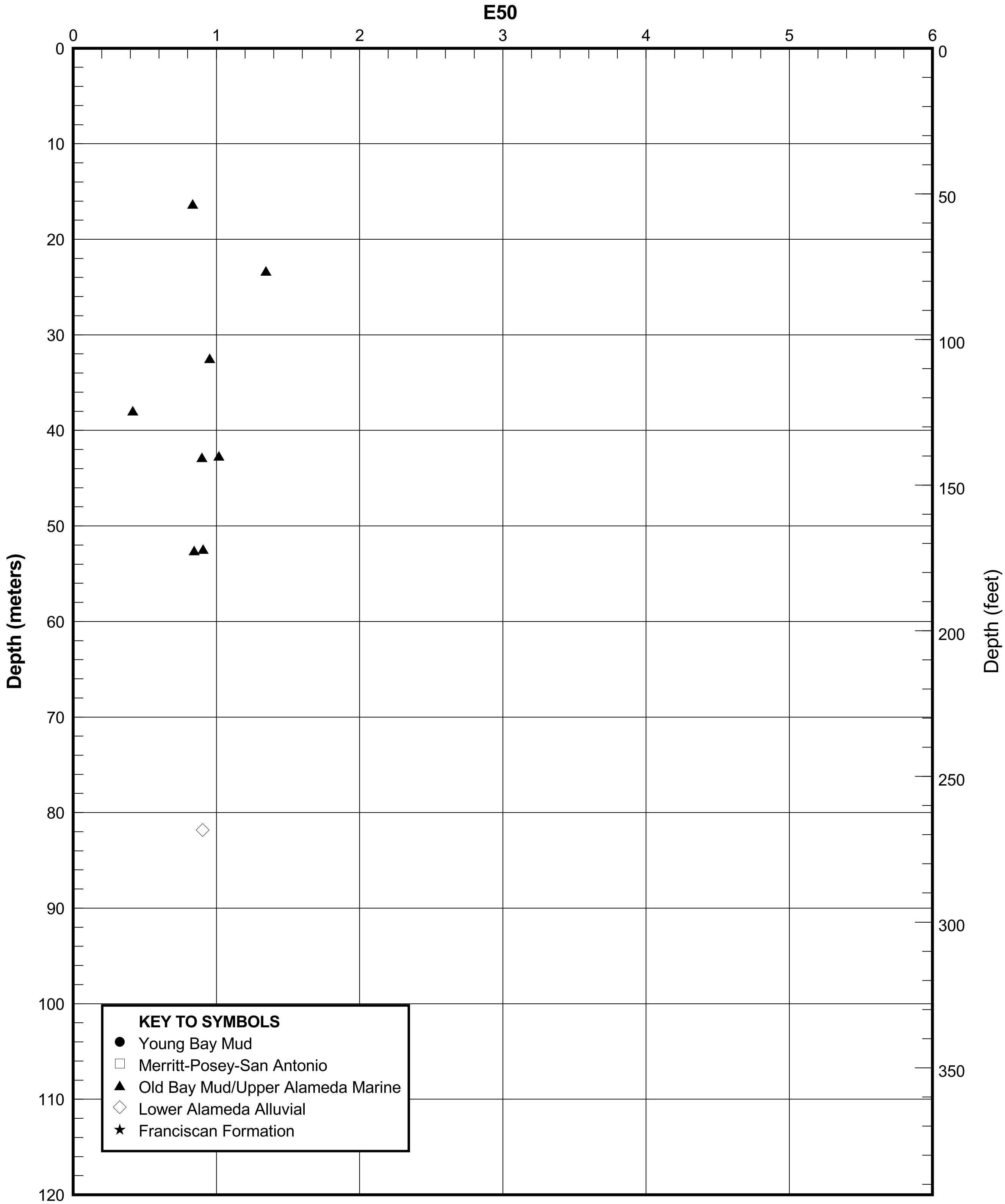
PLATE 98-82.17



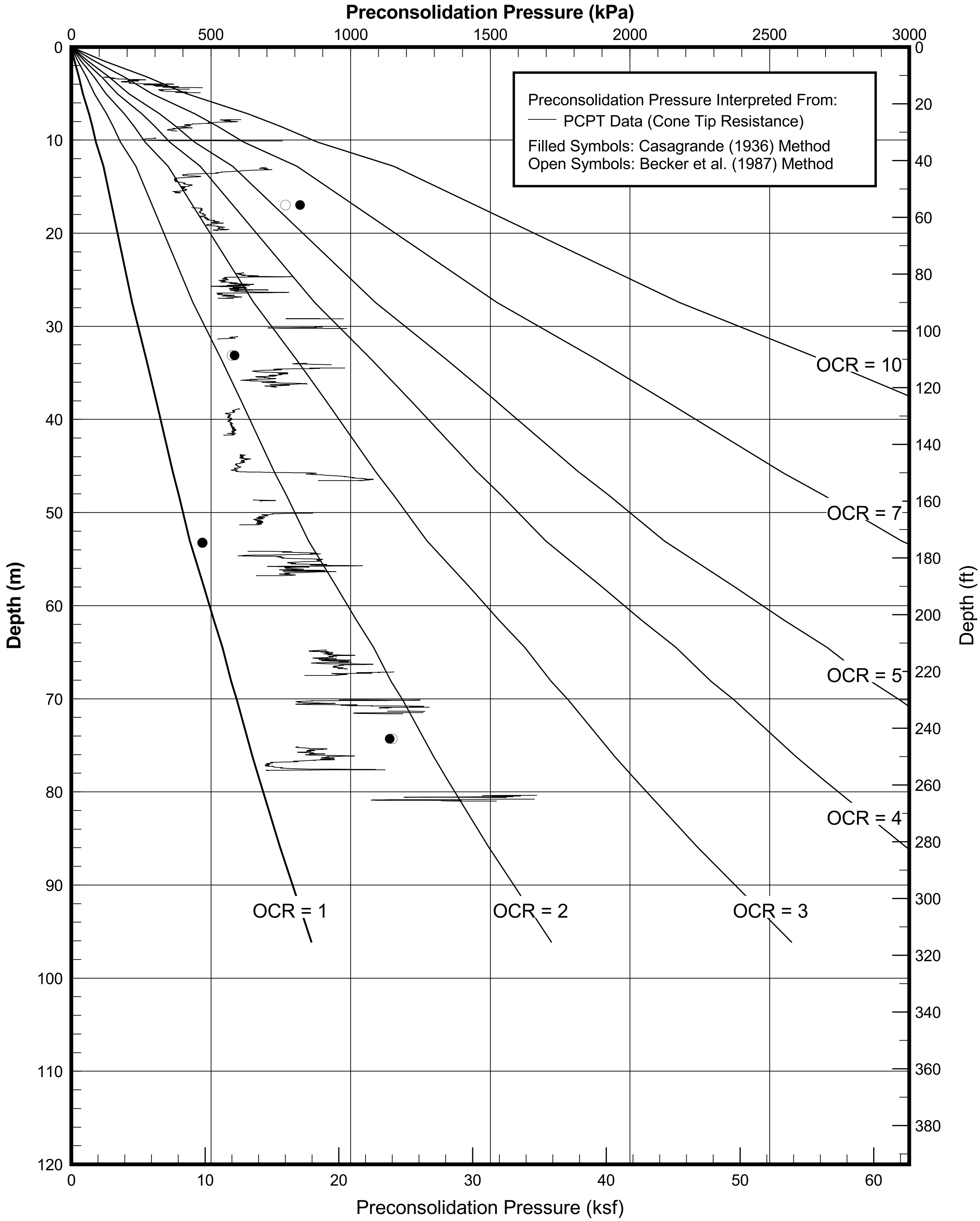
LIQUIDITY INDEX PROFILE
Boring 98-82
SFOBB East Span Seismic Safety Project



SENSITIVITY PROFILE
Boring 98-82
SFOBB East Span Seismic Safety Project



E50 PROFILE
Boring 98-82
SFOBB East Span Seismic Safety Project

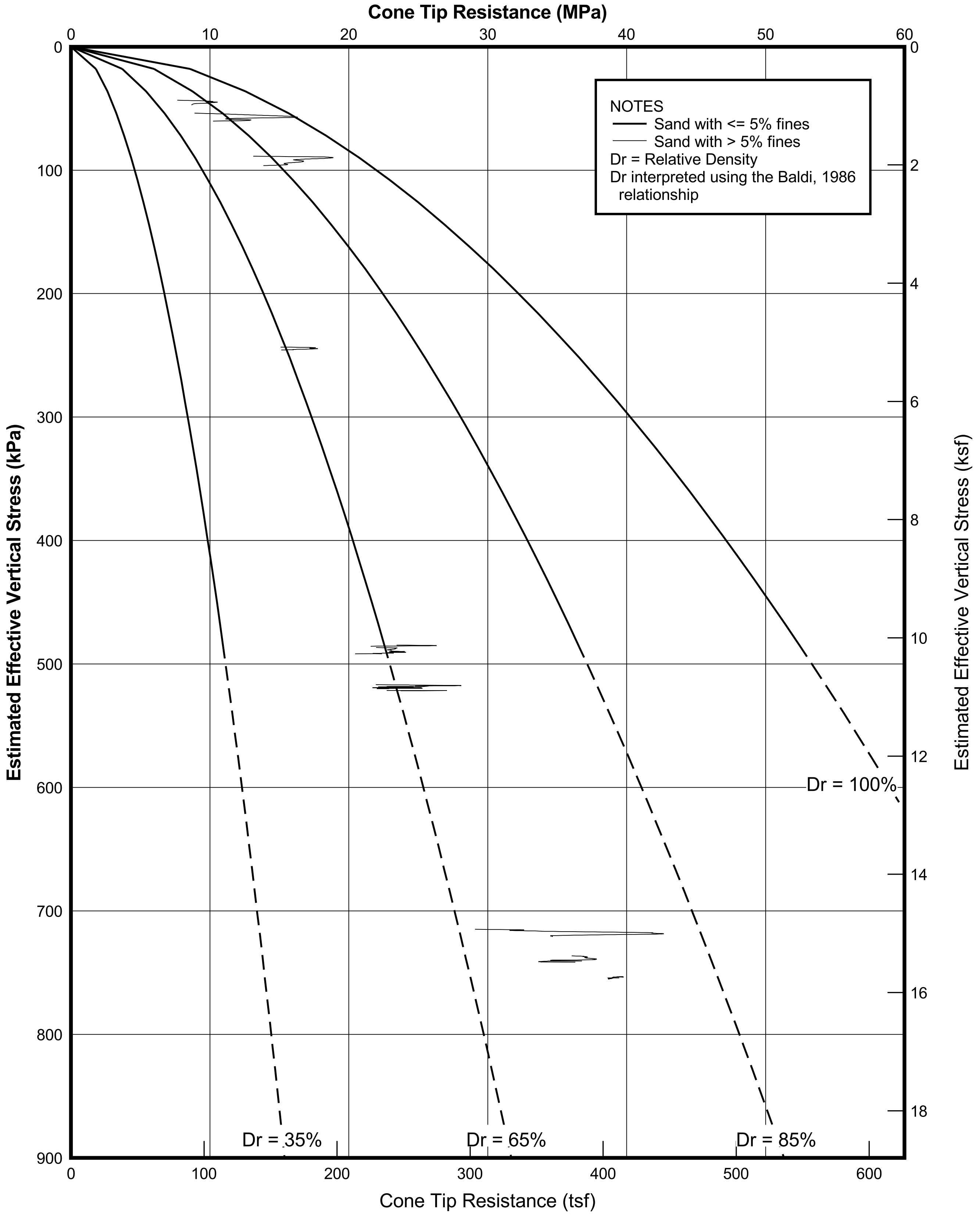


PRECONSOLIDATION PRESSURE INTERPRETED FROM CPT DATA

Boring 98-82

SFOBB East Span Seismic Safety Project

PLATE 98-82.21



RELATIVE DENSITY INTERPRETED FROM CPT DATA

Boring 98-82

SFOBB East Span Seismic Safety Project

PROJECT MEMORANDUM, PRELIMINARY PILE DRIVABILITY EVALUATION, SFOBB EAST SPAN SEISMIC SAFETY PROJECT, DATED MAY 13, 1998

FUGRO WEST, INC.

5855 Olivas Park Drive
Ventura CA 93003-7672
Tel: (805) 650-7000
Fax: (805) 650-7010

May 13, 1998
Fugro Project No. 98-42-0035

PROJECT MEMORANDUM

To: Mr. Mark Willian, Caltrans (2 copies)
Mr. Reid Buell, Caltrans (3 copies)
Dr. Brian Maroney, Caltrans (1 copy)
Mr. Po Lam, Earth Mechanics (3 copies)

From: David Menzies, Robert F. Stevens, and Tom McNeilan, Fugro

Subject: Preliminary Pile Drivability Evaluation, SFOBB East Span Seismic Safety Project

This report presents the results of our preliminary drivability study for 42-, 60-, and 96-in.-diameter pipe piles driven for the SFOBB East Span Project. The study was completed as part of the Task Order No. 3 authorization for Caltrans Contract 59A0053. This study was completed in two phases, Phase I and Phase II, to respond to changes in the pile wall thickness schedule during preliminary pile design. Interoffice memos were submitted on May 1 and May 11 to address the immediate needs of the T.Y. Lin/M&N structural design personnel. Detailed discussions of these memos are presented within this report.

Principal Findings

Our extensive experience with driving over 1,000 large-diameter offshore piles has shown that blow counts predicted for the lower bound coring case will generally give the best estimate of the field blow counts. Our analysis was performed in two phases, Phase I and II, as pile design progressed and the pile dimensions changed (see Plates 4 through 8). Tabulated below are predicted blow counts at 275-ft penetration (i.e., driven to the top of the Lower Alameda formation) and dynamic stresses for the three pile sizes considered, driven with ten different hammers.

Phase I Results

Pile Diameter (m / inch)	Hammer Type	Predicted Blow Counts (bpf)	Maximum Dynamic Stress (ksi)
1.5 / 60	Menck MRBS 3000	35 to 65	23.5
1.5 / 60	Vulcan 560	37 to 70	24.0
1.5 / 60	Conmaco 6850	30 to 65	21.2
1.5 / 60	IHC S-250	95 to 278	33.1
2.5 / 96	Menck MRBS 5000	30 to 95	21.6
2.5 / 96	Vulcan 5100	45 to 107	23.3
2.5 / 96	Conmaco 6850	45 to 130	19.0
2.5 / 96	IHC S-400	120 to 785	33.0

Phase II Results

Pile Diameter (m / inch)	Hammer Type	Predicted Blow Counts (bpf)	Maximum Dynamic Stress (ksi)
1.0 / 42	IHC S-250	70 to 658	29.5
1.0 / 42	IHC S-400	35 to 105	34.5
1.0 / 42	IHC S-500	29 to 74	36.0
1.5 / 60	IHC S-400	85 to 626	36.0
1.5 / 60	IHC S-500	66 to 292	39.0
1.5 / 60	Menck MHU-1000	20 to 42	45.7
2.5 / 96	IHC S-500	66 to 292	27.0
2.5 / 96	Menck MHU-1000	32 to 90	41.6

Pile refusal is likely to occur for most of the pile hammer combinations if it is attempted to drive the piles into very dense sand layers below 275-ft penetration (i.e., into the lower Alameda formation). The Menck MHU-1000 hammer cannot be used to drive the 60-in.-diameter piles without the possibility of yielding the steel as presently designed. Details of the above results are discussed in the following sections.

General Soil Conditions

Our evaluation of pile drivability is based on recently completed soil borings. Boring 98-10 was drilled at Zone 3, NAD 1983 coordinates X = 1,837,246 m and Y = 648,003 m. Soil conditions encountered in Boring 98-10 are considered typical of the soils along the Skyway section, where most of the steel pipe piles will be driven. Soil conditions are tabulated below to the depth of interest for Boring 98-10:

Stratum	Penetration (ft)		Description
	From	To	
I	0	12	Very soft to firm fat clay
II	12	33	Medium dense to dense silty fine sand
III	33	43	Firm fat clay
IV	43	67	Medium dense to dense silty fine sand
V	67	80	Very dense fine sand
VI	80	195	Very stiff to hard fat clay
VII	195	212	Dense to very dense sandy silt
VIII	212	275	Hard fat clay
IX	275	298	Very dense fine to coarse sand
X	298	309	Hard fat clay
XI	309	317	Very dense silty fine sand
XII	317	327	Hard fat clay
XIII	327	337	Very dense clayey gravel

Generally, the piles will be driven to the top of the lower Alameda formation (275-ft penetration for Boring 98-10), depending upon the required axial pile capacity. The soil profile is presented through the Lower Alameda formation to the top of the bedrock (Franciscan formation) to evaluate difficult driving in the lower Alameda formation. It is worth noting, that the water depth and depth of the lower Alameda formation will vary along the alignment of the bridge. Pile drivability should be evaluated for final pile makeup (increase in length) once final pile design is completed.

A Roman numeral representing each stratum is shown in the above tabulation, as well as on the resistance to driving and predicted blow count plates. Soils are naturally formed materials and their properties are likely to be variable, as they are controlled by nonuniform geologic depositional processes and post-depositional events. Soil strata may change in thickness, density, and soil type within relatively short horizontal and vertical distances. Because soil borings provide information at discrete intervals, some soil property variations may not be detected. Subsequent recommendations contained in this report were developed assuming that soil conditions as revealed by the borings are continuous throughout the general area. Consideration of possible stratigraphic changes, faulting, or other differences in soil conditions that could influence pile drivability is beyond the scope of this investigation.

Evaluation of Pile Drivability

Curves of soil resistance to driving were computed for both coring and plugged conditions using procedures recommended by Stevens, Wiltsie, and Turton (1982), and are presented on Plates 1 through 3 for 42-, 60- and 96-in.-diameter piles, respectively. When a pile cores, relative movement between the pile and soil occurs both on the outside and inside of the pile wall. The end bearing area is only the cross-sectional area of steel at the driving shoe. When a pile plugs, the soil plug moves with the pile during driving. Shaft resistance is mobilized only on the outer wall. The end bearing area is the gross area of the pile. The lower and upper bound resistance curves represent experience gained from previous projects. Generally, the lower bound coring case is the most representative of piles during continuous driving into predominantly clay soils.

Wave equation analyses were performed using the hammer, pile, and soil parameters given on Plates 5 and 6, for Phase I and on Plates 7 through 9, for Phase II. The differences in the two phases are related to the pile makeup, which changed during our analysis and will probably undergo future changes. The WAVEQ computer program, originally coded by Lowery et al (1969), was used to model the hammers. For air/steam hammers, the rated hammer energy, hammer efficiency, ram weight, pile cap weight, and cushion properties are required. Driving system performance parameters were determined from our data base. For the hydraulic hammers, the GRLWEAP (1997) program was used to model pile stresses. For hydraulic hammers, the ram impacts directly on the pile cap. A cushion is not used.

The soil quake and damping parameters recommended by Roussel (1979) were used in our wave equation analyses. These parameters were determined from a comprehensive correlation study performed for large-diameter offshore piles in which the driving records of 58 piles at 15 offshore sites in the Gulf of Mexico were analyzed. The side and point quake are assumed equal, with a magnitude of 0.10 in. for stiff to hard clay, silt, and sand. Side damping in clay decreases with increasing shear strength, which is in agreement with the laboratory test results of Coyle and Gibson (1970) and Heerema (1979). Point damping of 0.15 sec/ft is recommended for firm to hard clay, silt, and sand. The range of soil quake and damping values are specified on Plates 5 through 9.

Results of Wave Equation Analyses

Our extensive experience with driving large-diameter offshore piles has shown that blow counts predicted for the coring case will generally give the best estimate of the field blow counts. Predicted blow counts are presented on Plates 9 through 16 for various hammers driving the 60- and 96-in.-diameter pipe piles with soil resistances based on Boring 98-10 for Phase I. Phase I examined air-steam and hydraulic hammers typically used in the Gulf of Mexico. Phase II examined hydraulic hammers which were thought to be available and to offer better construction flexibility. The blow counts predicted during the Phase II effort are shown on Plates 17 through 24.

Results from Phase I indicates that the 60-in.-diameter pipe piles may be driven to 275-ft penetration with any of the proposed hammers (Plates 9 through 12). For a Menck MRBS 3000 hammer, blow counts are expected to range from 20 to 35 bpf at 195-ft penetration, and from 35 to 65 bpf at 275-ft penetration. For a Vulcan 560 hammer, blow counts are expected to range from 22 to 38 bpf at 195-ft penetration, and from 37 to 70 bpf at 275-ft penetration. For a Conmaco 5700 hammer, blow counts are expected to range from 20 to 30 bpf at 195-ft penetration, and from 30 to 65 bpf at 275-ft penetration. For an IHC S-250 hammer, blow counts are expected to range from 55 to 90 bpf at 195-ft penetration, and from 95 to 278 bpf at 275-ft penetration. If the piles plug, blow counts in the Stratum IX sand (275- to 298-ft penetration) range from 125 to 415 bpf for a Menck MRBS 3000 hammer, from 140 to 497 bpf for a Vulcan 560 hammer, and from 133 to 580 bpf for a Conmaco 5700 hammer. Therefore, the three hammers may become marginal to drive the piles through Stratum IX, and refusal is expected with an IHC S-250 hammer. If the piles core, blow counts at 337-ft penetration range from 65 to 312 bpf for a Menck MRBS 3000 hammer, from 70 to 338 bpf with a Vulcan 560 hammer, and from 65 to 522 bpf with a Conmaco 5700 hammer.

For Phase I, a 36 ksi yield strength was assumed for all piles. The maximum driving stresses computed in our wave equation analyses for a hammer efficiency of 85 percent are 21.1 ksi for a Conmaco 5700 hammer, 23.5 ksi for a Menck MRBS 3000 hammer, 24.0 ksi for a Vulcan 560 hammer, and 33.1 ksi for an IHC S-250 hammer. Therefore, it would appear that any of the proposed hammers could be used without overstressing the piles.

Results from Phase I indicate that the 96-in.-diameter pipe piles may be driven to 275-ft penetration with any of the proposed hammers (Plates 13 through 16). For a Menck MRBS 5000 hammer, blow counts are expected to range from 20 to 40 bpf at 195-ft penetration, and from 30 to 95 bpf at 275-ft penetration. For a Vulcan 5100 hammer, blow counts are expected to range from 22 to 47 bpf at 195-ft penetration, and from 45 to 105 bpf at 275-ft penetration. For a Conmaco 6850 hammer, blow counts are expected to range from 35 to 45 bpf at 195-ft penetration, and from 45 to 130 bpf at 275-ft penetration. For an IHC S-400 hammer, blow counts are expected to range from 55 to 120 bpf at 195-ft penetration, and from 120 to 785 bpf (i.e., essentially refusal) at 275-ft penetration. If pile is driven into the lower Alameda formation and the piles plug, blow counts in the Stratum IX sand, range from 372 bpf to refusal for a Menck MRBS 5000 hammer, and from 405 bpf to refusal for a Vulcan 5100 hammer. Refusal is expected with the Conmaco 6850 and IHC S-400 hammers. If the piles core, blow counts at 337-ft penetration range from 60 to 360 bpf for a Menck MRBS 5000 hammer, and from 67 to 330 bpf for a Vulcan 5100 hammer.

The maximum driving stresses computed in our wave equation analyses for a hammer efficiency of 85 percent are 19.0 ksi for a Conmaco 6850 hammer, 21.6 ksi for a Menck MRBS 5000 hammer, 23.3 ksi for a Vulcan 5100 hammer, and 33.0 ksi for an IHC S-500 hammer. Therefore, any of the proposed hammers could be used without overstressing the piles.

The Phase II results indicate that the 42-in.-diameter pipe piles may be driven to 275-ft penetration with any of the proposed hammers for the lower bound coring resistance (Plates 17 through 19). For a IHC S-250 hammer, blow counts are expected to range from 32 to 55 bpf at 195-ft penetration, and from 70 to 658 bpf (close to refusal) at 275-ft penetration. For a IHC S-400 hammer, blow counts are expected to range from 20 to 31 bpf at 195-ft penetration, and from 35 to 105 bpf at 275-ft penetration. For an IHC S-500 hammer, blow counts are expected to range from 17 to 26 bpf at 195-ft penetration, and from 29 to 74 bpf at 275-ft penetration. It is not anticipated that the 42-in.-diameter pile will be driven below 275-ft penetration. However, blow counts at these depths are presented on Plates 17 through 19 and indicate pile refusal for all hammers when using the upper bound soil resistances.

The Phase II pile design calls for higher strength steel to be used for pile design. We have assumed a 52 ksi yield strength. The maximum driving stresses computed in our wave equation analyses for a hammer efficiency of 95 percent are 29.5 ksi for a IHC S-250 hammer, 34.5 ksi for a IHC S-500 hammer, and 36.0 ksi for a IHC S-500 hammer. Therefore, any of the proposed hammers could be used without overstressing the piles.

The Phase II results indicated that the 60-in.-diameter pipe piles may be driven to 275-ft penetration with any of the proposed hammers for the lower bound coring resistance (Plates 20 through 22). For a IHC S-400 hammer, blow counts are expected to range from 43 to 80 bpf at 195-ft penetration, and from 85 to 626 bpf at 275-ft penetration. For a IHC S-500 hammer, blow counts are expected to range from 37 to 65 bpf at 195-ft penetration, and from 66 to 292 bpf at 275-ft penetration. For a Menck MHU-1000 hammer, blow counts are expected to range from 12 to 22 bpf at 195-ft penetration, and from 20 to 42 bpf at 275-ft penetration. It is not anticipated that the 42-in.-diameter pile will be driven below 275-ft penetration. Blow counts below 275-ft penetration are presented on Plates 20 through 22 and indicate pile refusal for the IHC S-400 and S-500 hammers for the upper bound coring and lower and upper bound plugged soil resistances. The Menck MHU-1000 hammer could drive the pile below 275-ft penetration, but the weight of the Menck hammer (about 334 kips) and high ram impact velocities may yield the pile.

The Phase II pile design calls for higher strength steel to be used for pile design. We have assumed a 52 ksi yield strength. The maximum driving stresses computed in our wave equation analyses for a hammer efficiency of 95 percent are 36.0 ksi for a IHC S-400 hammer, 39.0 ksi for a IHC S-500 hammer, and 45.7 ksi for a Menck MHU-1000 hammer. The maximum driving stress exceeds 90 percent of yield for the Menck MHU-1000 hammer.

Results from Phase II indicate that the 96-in.-diameter pipe piles may be driven to 275-ft penetration with any of the proposed hammers using the lower bound coring resistance (Plates 23 and 24). For a IHC S-500 hammer, blow counts are expected to range from 56 to 139 bpf at 195-ft penetration, and from 98 to 350 bpf at 275-ft penetration. For a Menck MHU-1000 hammer, blow counts are expected to range from 21 to 43 bpf at 195-ft penetration, and from 32 to 290 bpf at 275-ft penetration. It is not anticipated that the 42-in.-diameter pile will be driven below 275-ft penetration. Blow counts below 275-ft penetration are presented on Plates 23 and 24 and indicate pile refusal for the IHC S-500 hammers for upper bound coring and lower and upper bound plugged soil resistances. The Menck MHU-1000 hammer could drive the pile below 275-ft penetration, but pile refusal may occur for the upper bound plugged soil resistance.

The Phase II pile design calls for higher strength steel to be used for pile design. We have assumed a 52 ksi yield strength. The maximum driving stresses computed in our wave equation analyses for a hammer efficiency of 95 percent are 27.0 ksi for a IHC S-500 hammer and 41.6 ksi for a Menck MHU-1000 hammer. Therefore, any of the hammers could be used without overstressing the piles.

Evaluation of Pile Set-Up

Wave equation analyses were also performed to evaluate the increase in blow counts after short delays. During continuous driving, the clay surrounding a pile is remolded and large excess pore water pressures are generated. Because the excess pore pressures decrease rapidly with radial distance from the pile, water will begin to flow laterally out of the disturbed zone and the clay will consolidate. As pore pressures dissipate, pile capacity increases. Field measurements (Soderberg, 1962; Azzouz and Baligh, 1984; Whittle and Baligh, 1988; and Bogard and Matlock, 1990) have shown that the time required for driven piles to regain ultimate capacity can be relatively long.

Soderberg (1962) solved the radial consolidation problem with a finite difference approach. His solution is presented as a plot of percent pore pressure dissipation at the pile surface versus a dimensionless time factor, T. The time factor is defined as:

$$T = c_h t / r_p^2$$

where: c_h = coefficient of radial consolidation
t = time
r_p = pile radius

It is assumed that the rate of pore pressure dissipation corresponds to the rate of set-up. A coefficient of radial consolidation of 0.185 ft^2/day, back-calculated by Stevens (1974) from the Eugene Island pile load test data for normally consolidated clay, was used in our computations. The soil resistance to driving was determined for a delay of 0.5, 1, and 2 days.

The regain in strength is slow for large diameter piles. For the 96-in.-diameter piles, the regain in strength is only 5 percent after a 0.5-day delay, 7 percent after a 1-day delay, and 10 percent after a 2-day delay. Because the piles will initially drive plugged, add-ons should be made above or below the sand strata. Our evaluation of pile set-up indicates that there should be no difficulty restarting the piles with the proposed hammers above 275-ft penetration. We proposed to examine pile set-up in greater detail, applying soil characteristics representative of overconsolidated clays determined from SFOBB borings to our pile setup models.

Evaluation of Pile Stick-Up

For the Phase I pile wall-thickness schedule, the maximum allowable pile stick-up for hammer placement was determined. The yield strength of the steel was assumed to be 36 ksi. The following tables are for static conditions only:

60-Inch-Diameter Pile With 2-Inch Wall

	Maximum Pile Stick-Up, Feet			
Pile Batter	1:12	1:6	1:4	1:3
Vulcan 560	198	156	127	107
Menck 3000	206	165	137	117
Conmaco 5700	183	139	110	91

96-Inch-Diameter Pile With 2-Inch Wall

	Maximum Pile Stick-Up, Feet			
Vulcan 560 Menck 5000 Conmaco 6850	313 290 294	258 232 236	220 193 196	193 165 169

Also, the sum of the stresses due to the impact of the hammer (driving stress) and the axial and bending stresses due to the weight of the hammer during driving should not exceed the minimum yield stress of the steel. The results of our drivability study show that there should be no difficulty restarting the piles above 275-ft penetration with any of the air/steam hammers. Driving stresses can be reduced to an acceptable level for these hammers by decreasing the hammer efficiency or increasing the pile wall-thickness schedule.

For the Phase II pile wall-thickness schedule, the maximum allowable pile stick-up was determined from dynamic considerations (during driving), which was the governing case. For the Phase II piles, the yield strength of the steel was assumed to be 52 ksi. Hammer weights were determined from available literature and the center of gravity was assumed to be located at the mid height of hammer unless specified otherwise in the literature. The following tables considers both static and dynamic stresses for 1 to 6 maximum battered pile:

Pile Diameter (m / ft)	Hammer Type	Estimated Dynamic Stress (ksi)	Section Thickness (inch)	Estimated Max. Stickup Length (feet)
2.5 / 96	Menck MHU-1000	41.6	1.50 2.25 2.75	85 120 136
2.5 / 96	IHC S-500	27.0	1.50 2.25 2.75	262 279 285
1.5 / 60	Menck MHU-1000	45.7	1.50 2.00 2.25	<30 <30 <30
1.5 / 60	IHC S-500	39.0	1.50 2.00 2.25	121 139 145
1.5 / 60	IHC S-400	36.0	1.50 2.00 2.25	159 176 182
1.0 / 42	IHC S-500 IHC S-400	36.0 34.5	1.00 1.25 1.00 1.25	56 69 76 91
1.0 / 42	IHC S-250	29.5	1.00 1.25	144 159

The above table was produced given the following assumptions:

- API RP 2A (1993) Method was used to calculate stresses,
- A maximum pile batter of 1 on 6 was assumed
- The yield stress of 52 ksi was used, and
- Dynamic stresses were increased by 10 percent for the 60- and 96-inch piles to account for the variable wall-thickness and the uncertainty of hammer add-on lengths for the Phase II piles.

A re-analysis of the data may more accurately define dynamic stresses once pile dimensions, wall-thickness schedules, lengths, and add-on sections are finalized.

Warranty

The results presented in this report are based on soil conditions revealed by borings at the boring locations only. Lateral variation in subsurface conditions across the site could result in variable blow counts. Deviations between the observed and predicted blow counts may indicate soil conditions which are different from those assumed for this study, and may require further investigation.

Fugro warrants that its services with respect to this study were performed with a degree of care and skill equal to that ordinarily exercised under similar conditions by reputable members of our profession practicing in the same or similar locality. No other warranty, express or implied, is made or intended.

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Azzouz, A.S. and Baligh, M.M. (1984), Behavior of Friction Piles in Plastic Empire Clays, Vol. 2, Report No. R84-14, Construction Facilities Division, Civil Engineering Department, Massachusetts Institute of Technology.

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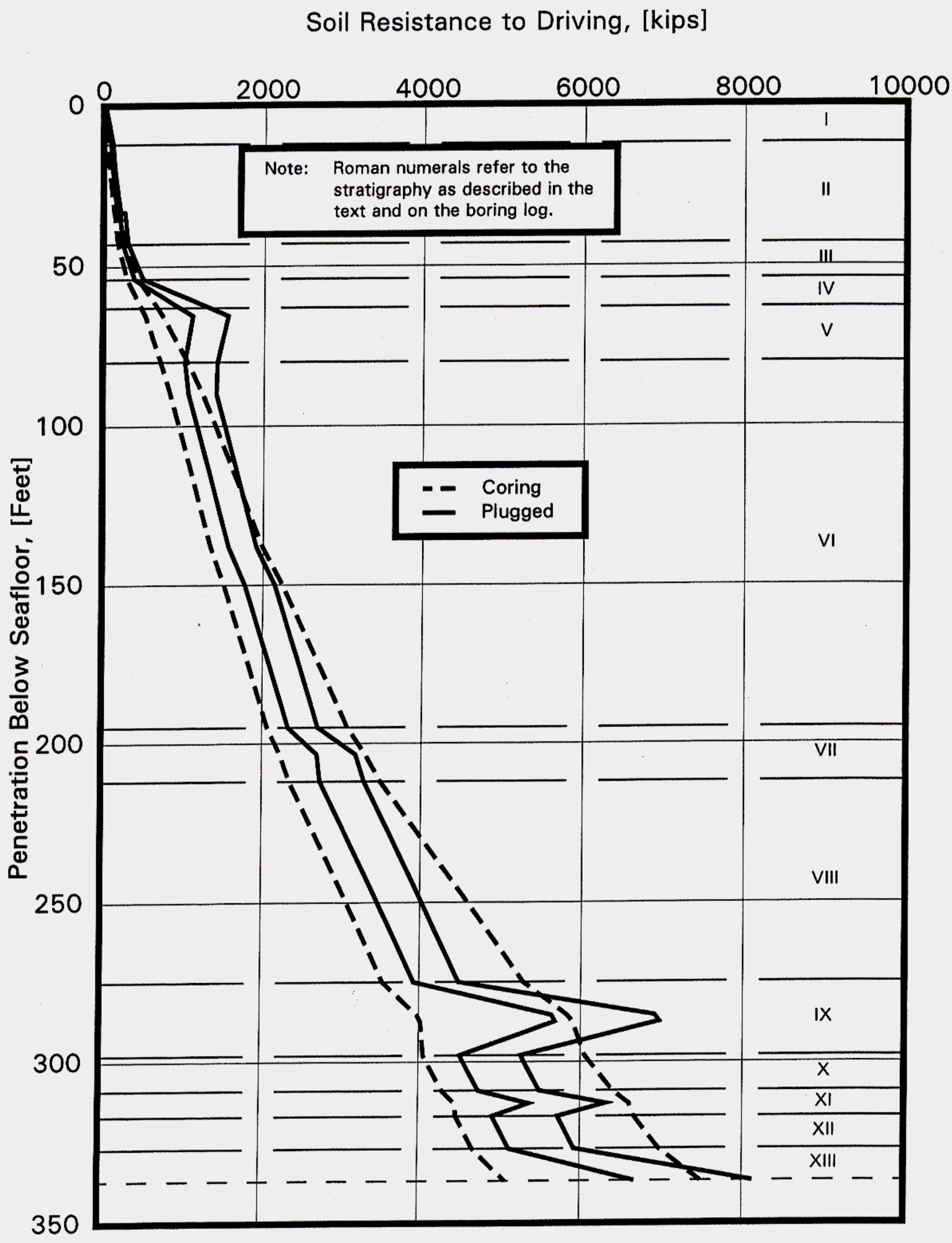
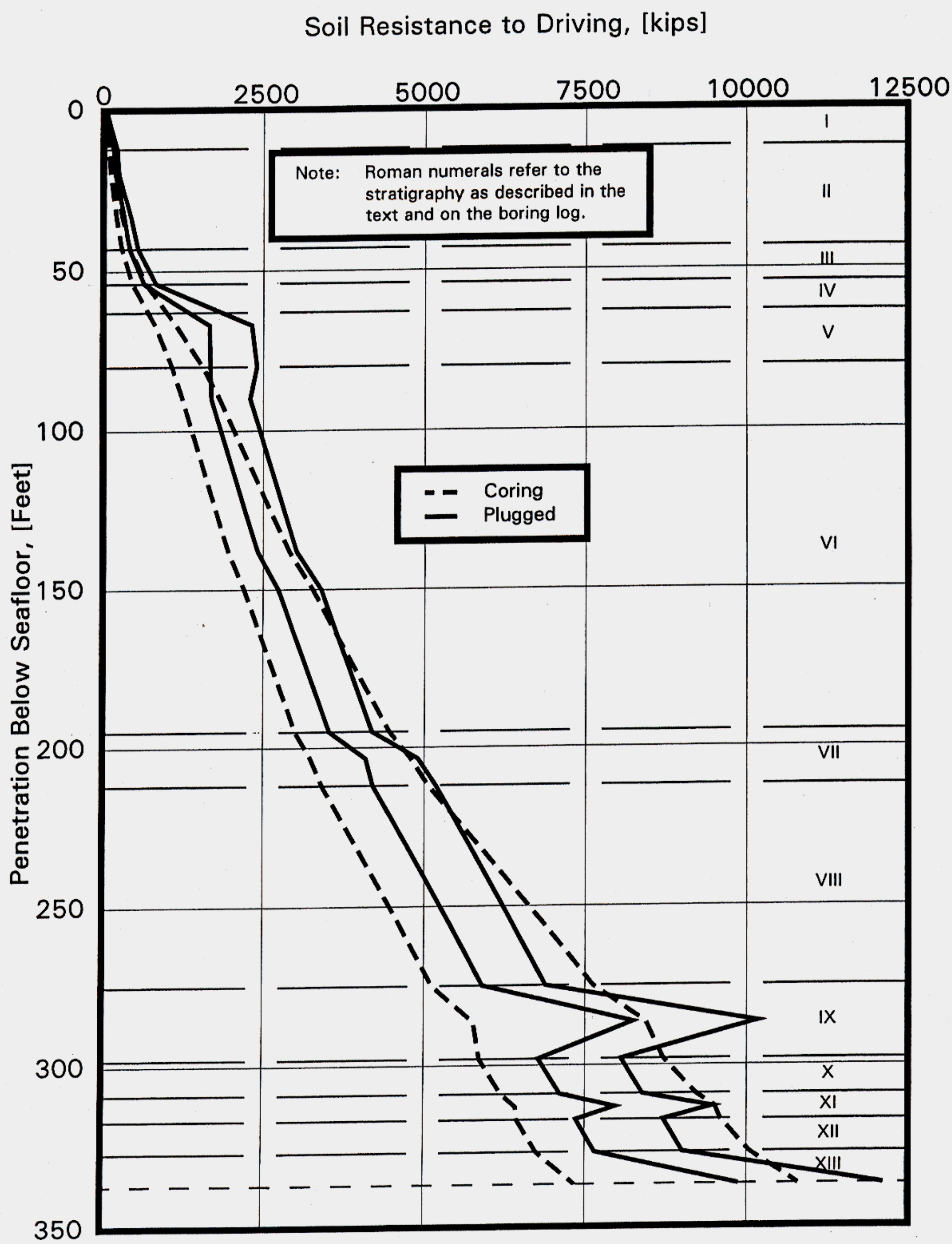
Whittle, A.J. and Baligh, M.M. (1988), The Behavior of Pile Supporting Tension Leg Platforms, Final Report Phase III, Construction Facilities Division, Civil Engineering Department, Massachusetts Institute of Technology.

Attachments: Plates 1 through 3 ...... Estimated Soil Resistance to Driving
Plates 4 and 8............. Summary of Wave Equation Parameters
Plates 9 through 24 .... Predicted Blow Counts
Plates 25 through 27 .. Driving Resistance - Blow Count Curves



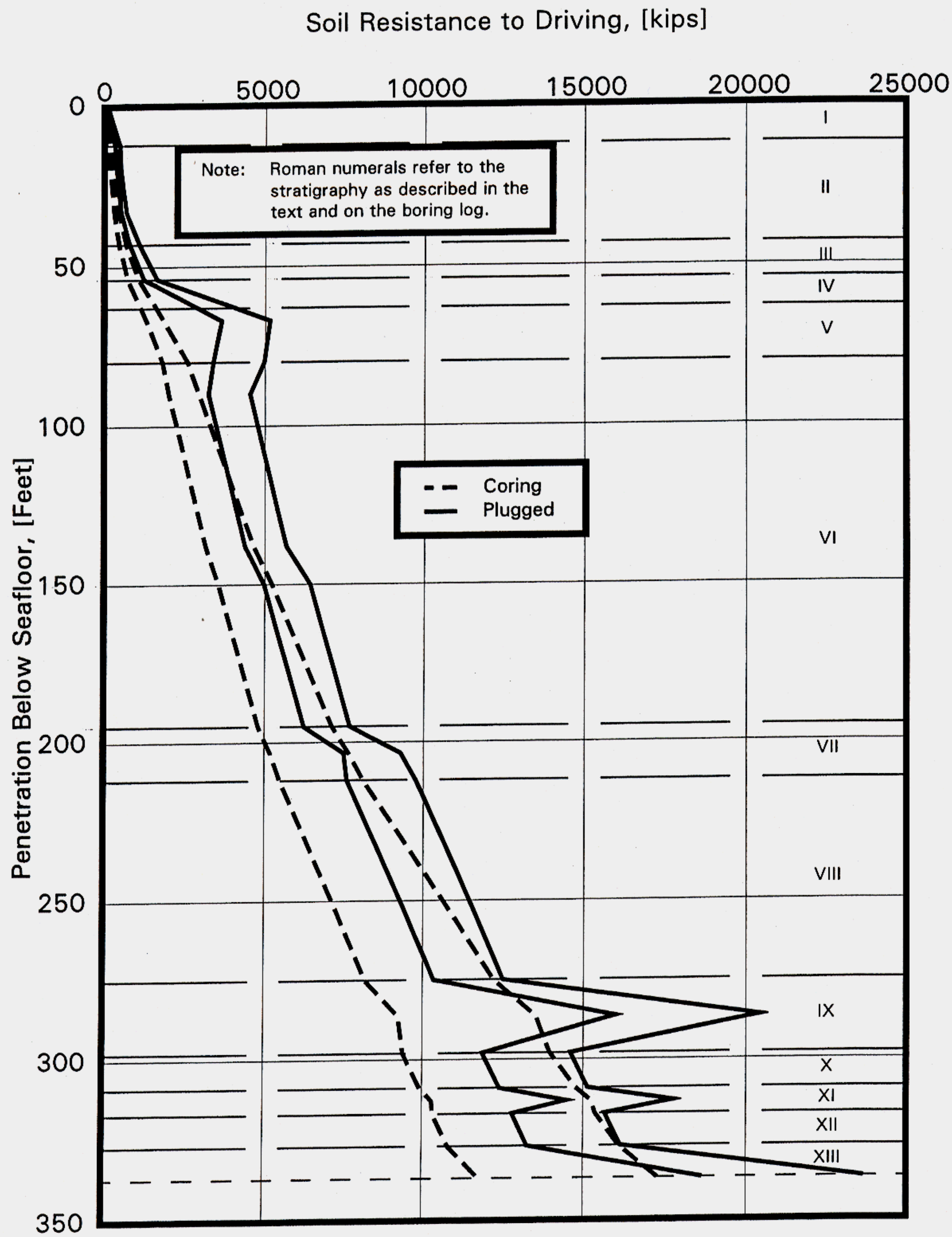
SOIL RESISTANCE TO DRIVING
42-in.-Diameter Pipe Piles
Boring 98-10
SFOBB East Span Replacment Project

Drawn By: DT Date: 3/12/98
Checked By: Date:
Approved By: Date:



SOIL RESISTANCE TO DRIVING
60-in.-Diameter Pipe Piles
Boring 98-10
SFOBB East Span Replacment Project

Drawn By: PFS Date: 4/24/98
Checked By: DM Date: 5/11/98
Approved By: Date:



SOIL RESISTANCE TO DRIVING
96-in.-Diameter Pipe Piles
Boring 98-10
SFOBB East Span Replacment Project

Drawn By: RFS Date: 4/29/98
Checked By: [illegible] Date: 5/11/98
Approved By: Date:

Date: 5/11/98

Drawn By: DT

Date:
Date:

Checked By:
Approved By:

HAMMER PROPERTIES

	IHC-S-250	Vulcan 560	Menck 3000	Conmaco 5700
Rated Energy, ft-lb	184,640	312,500	325,480	350,000
Hammer Efficiency, %	95	85	85	85
Weight of Ram, lb	27,600	62,500	66,100	70,000
Weight of Pile Cap, lb	7,700	45,900	34,800	56,800
Cushion Stiffness, lb/in.	--	9.0×10^7	5.5×10^7	5.0×10^7
Coefficient of Restitution				
Cushion	0.98	0.80	0.80	0.80
Pile Cap on Pile	0.95	0.95	0.95	0.95

PILE PROPERTIES

Diameter, in.	60
Wall Thickness, in.	2.00
Shoe Thickness, in.	2.25
Unit Weight, pcf	492
Modulus, psi	29.6×10^6

SOIL PROPERTIES

Quake, in.	
Side	0.10
Tip	0.10
Damping, sec/ft	
Side	0.050 to 0.075
Tip	0.15
Tip Resistance	2 to 65

SUMMARY OF WAVE EQUATION PARAMETERS
Phase I, 60-in.-Diameter Pipe Piles
SFOBB East Span Replacement Project

Date: 5/11/98

Drawn By: DK

HAMMER PROPERTIES

	IHC-S-400	Vulcan 5100	Menck 5000	Conmaco 6850
Rated Energy, ft-lb	294,600	500,000	542,470	510,000
Hammer Efficiency, %	95	85	85	85
Weight of Ram, lb	44,300	100,000	110,200	85,000
Weight of Pile Cap, lb	12,300	69,500	66,100	86,800
Cushion Stiffness, lb/in.	--	11.5×10^7	7.0×10^7	5.0×10^7
Coefficient of Restitution				
Cushion	0.98	0.80	0.80	0.80
Pile Cap on Pile	0.95	0.95	0.95	0.95

PILE PROPERTIES

Diameter, in.	96
Wall Thickness, in.	2.00
Shoe Thickness, in.	2.25
Unit Weight, pcf	492
Modulus, psi	29.6×10^6

SOIL PROPERTIES

Quake, in.	
Side	0.10
Tip	0.10
Damping, sec/ft	
Side	0.050 to 0.075
Tip	0.15
Tip Resistance	2 to 75

Date:
Date:

Checked By:
Approved By:

SUMMARY OF WAVE EQUATION PARAMETERS
Phase I, 96-in.-Diameter Pipe Piles
SFOBB East Span Replacement Project

Date: 5/11/98
Drawn By: [illegible]

Date:
Date:

Checked By:
Approved By:

HAMMER PROPERTIES

	IHC-S-250	IHC-S-400	IHC-S-500
Rated Energy, ft-lb	184,640	294,600	369,000
Hammer Efficiency, %	95	95	95
Weight of Ram, lb	27,600	44,300	55,100
Weight of Pile Cap, lb	7,700	12,300	12,300
Cushion Stiffness, lb/in.	--	--	--
Coefficient of Restitution			
Cushion	0.98	0.98	0.98
Pile Cap on Pile	0.95	0.95	0.95

PILE PROPERTIES

Diameter, in.	42
Wall Thickness, in.	1.0
Shoe Thickness, in.	1.5
Unit Weight, pcf	492
Modulus, psi	29.6×10^6

SOIL PROPERTIES

Quake, in.	
Side	0.10
Tip	0.10
Damping, sec/ft	
Side	0.050 to 0.091
Tip	0.15
Tip Resistance	1 to 64

SUMMARY OF WAVE EQUATION PARAMETERS

Phase II, 42-in.-Diameter Pipe Piles
SFOBB East Span Replacement Project

Date: 5/11/98

Drawn By:

Date:
Date:

Checked By:
Approved By:

HAMMER PROPERTIES

	IHC-S-400	IHC-S-500	Menck MHU-1000
Rated Energy, ft-lb	294,600	396,000	737,700
Hammer Efficiency, %	95	95	95
Weight of Ram, lb	44,300	55,100	125,700
Weight of Pile Cap, lb	12,300	12,300	61,700
Cushion Stiffness, lb/in.	--	--	--
Coefficient of Restitution			
Cushion	0.98	0.98	0.98
Pile Cap on Pile	0.95	0.95	0.95

PILE PROPERTIES

Diameter, in.	60
Wall Thickness, in. (top half of pile)	1.75
Wall Thickness, in. (bottom half of pile)	1.00
Shoe Thickness, in.	2.25
Unit Weight, pcf	492
Modulus, psi	29.6×10^6

SOIL PROPERTIES

Quake, in.	
Side	0.10
Tip	0.10
Damping, sec/ft	
Side	0.050 to 0.084
Tip	0.15
Tip Resistance	2 to 65

SUMMARY OF WAVE EQUATION PARAMETERS
Phase II, 60-in.-Diameter Pipe Piles
SFOBB East Span Replacement Project

FUGRO

Date: 5/11/98

Drawn By: DJC

Date:
Date:

Checked By:
Approved By:

HAMMER PROPERTIES

	IHC-S-500	Menck MHU-1000
Rated Energy, ft-lb	396,000	737,700
Hammer Efficiency, %	95	95
Weight of Ram, lb	55,100	125,700
Weight of Pile Cap, lb	12,300	61,700
Cushion Stiffness, lb/in.	--	--
Coefficient of Restitution		
Cushion	0.98	0.98
Pile Cap on Pile	0.95	0.95

PILE PROPERTIES

Diameter, in.	96
Wall Thickness, in. (top half of pile)	2.75
Wall Thickness, in. (bottom half of pile	1.50
Shoe Thickness, in.	2.25
Unit Weight, pcf	492
Modulus, psi	29.6×10^6

SOIL PROPERTIES

Quake, in.	
Side	0.10
Tip	0.10
Damping, sec/ft	
Side	0.050 to 0.084
Tip	0.15
Tip Resistance	2 to 75

SUMMARY OF WAVE EQUATION PARAMETERS

Phase II, 96-in.-Diameter Pipe Piles
SFOBB East Span Replacement Project

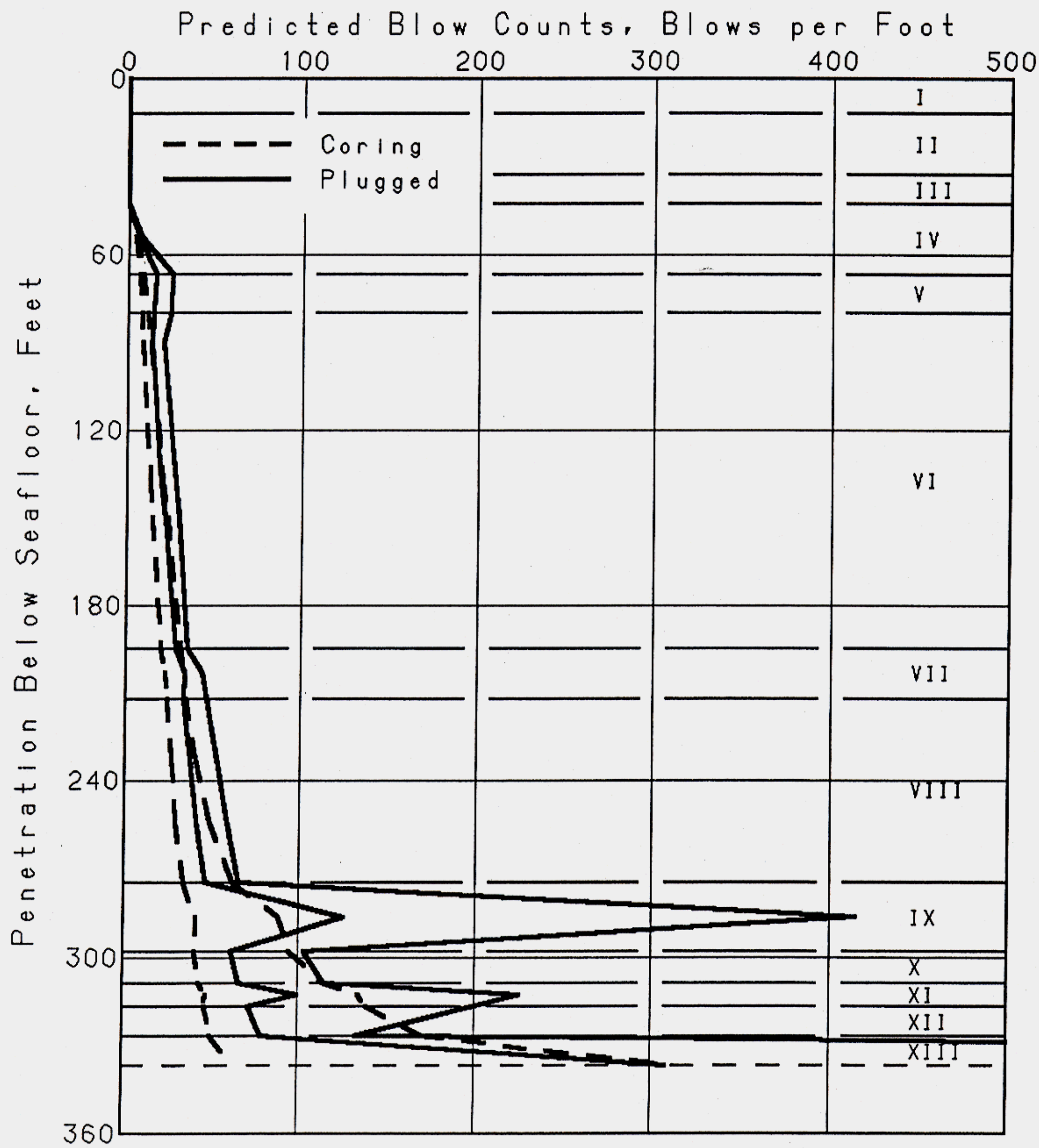
FUGRO

Date: 4/24/98

Drawn By: RLF

Date: 5/11/98
Date:

Checked By: DTr
Approved By:



PREDICTED BLOW COUNTS
Phase I, 60-in.-Diameter Pipe Piles
Menck MRBS 3000 Hammer
Boring 98-10
SFOBB East Span Replacement Project

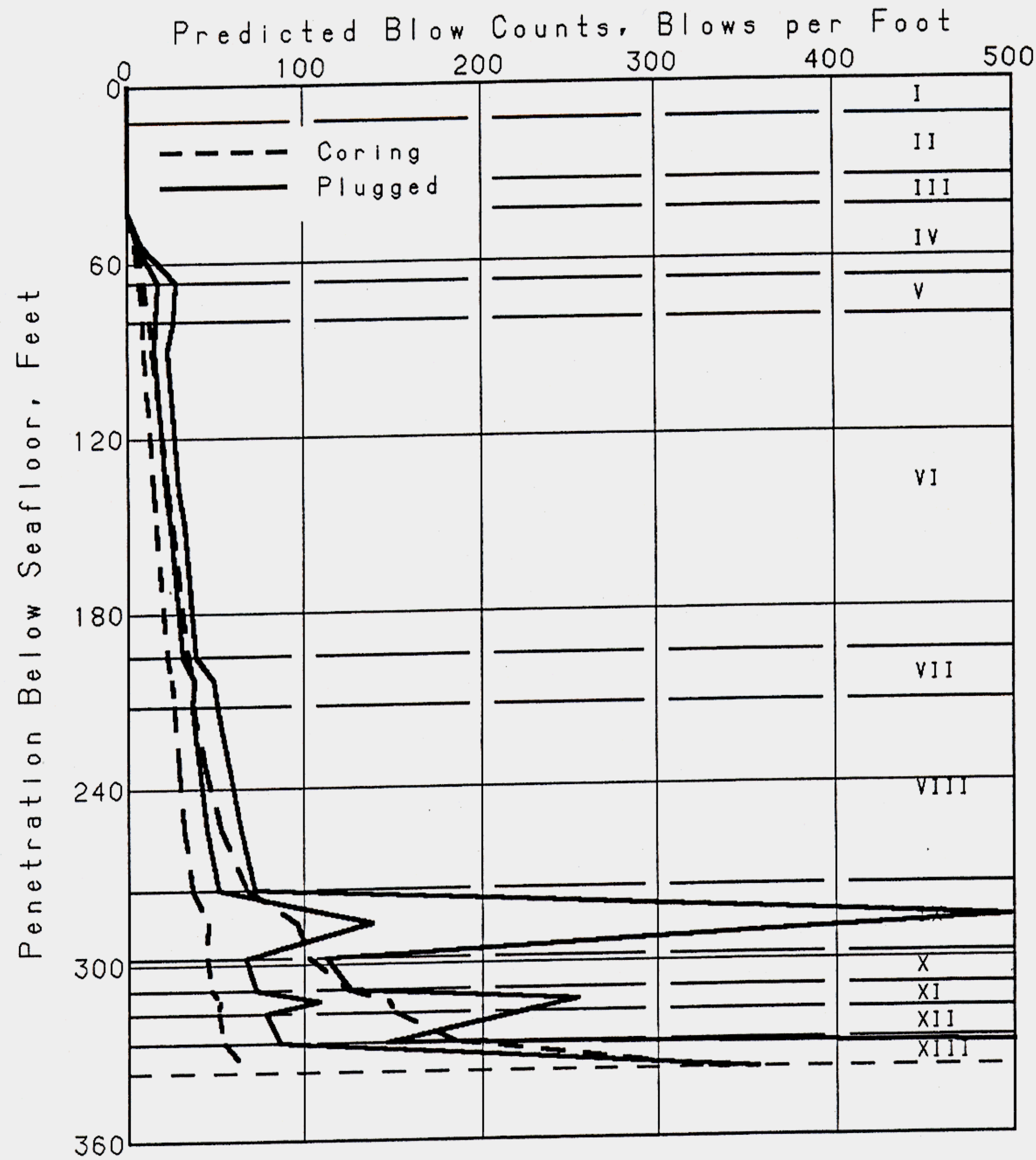
FUGRO

Date: 4/24/98

Drawn By: RFJ

Date: 5/11/98
Date:

Checked By:
Approved By:



PREDICTED BLOW COUNTS
Phase I, 60-in.-Diameter Pipe Piles
Vulcan 560 Hammer
Boring 98-10
SFOBB East Span Replacement Project

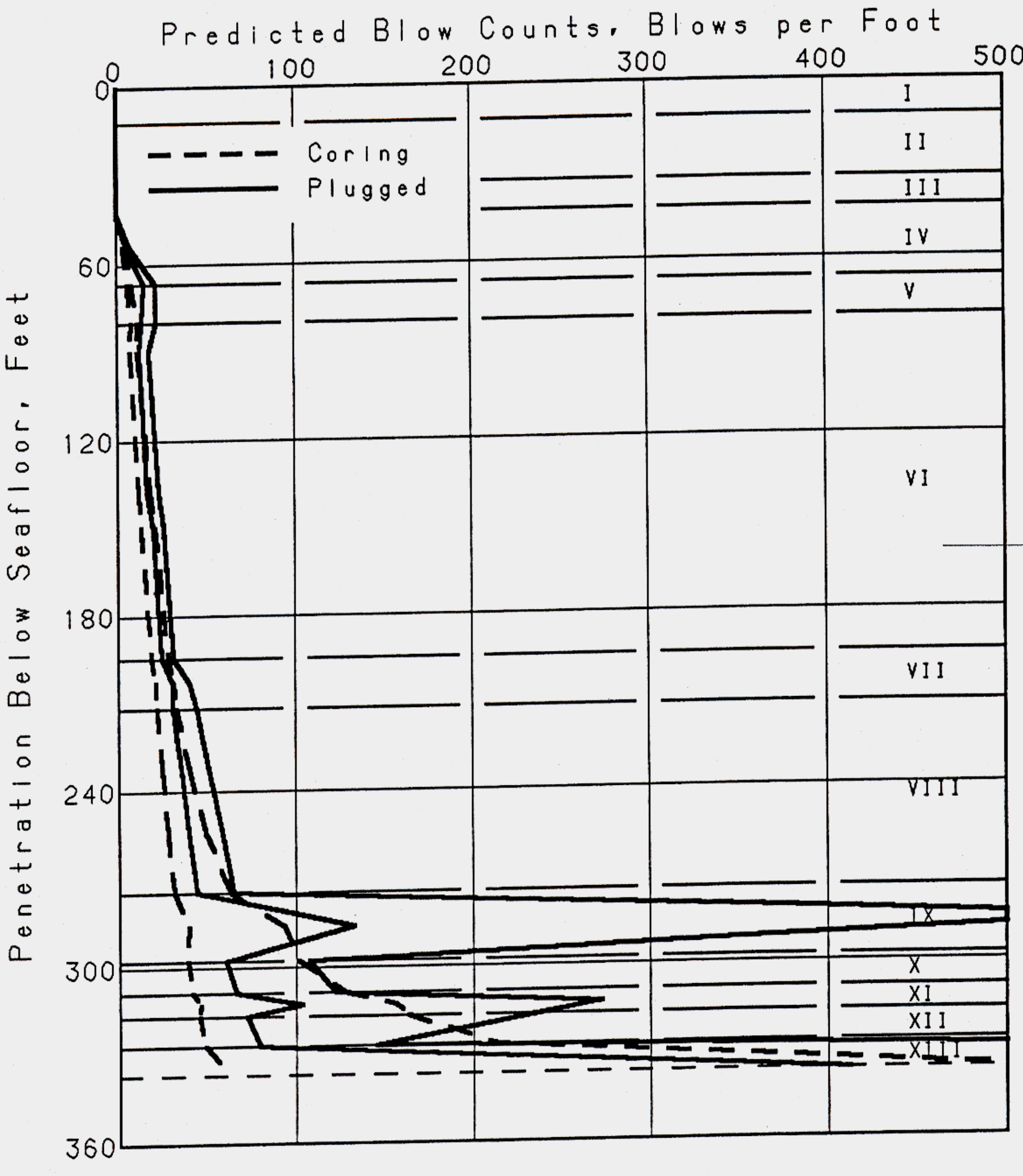
FUGRO

Date: 4/24/98

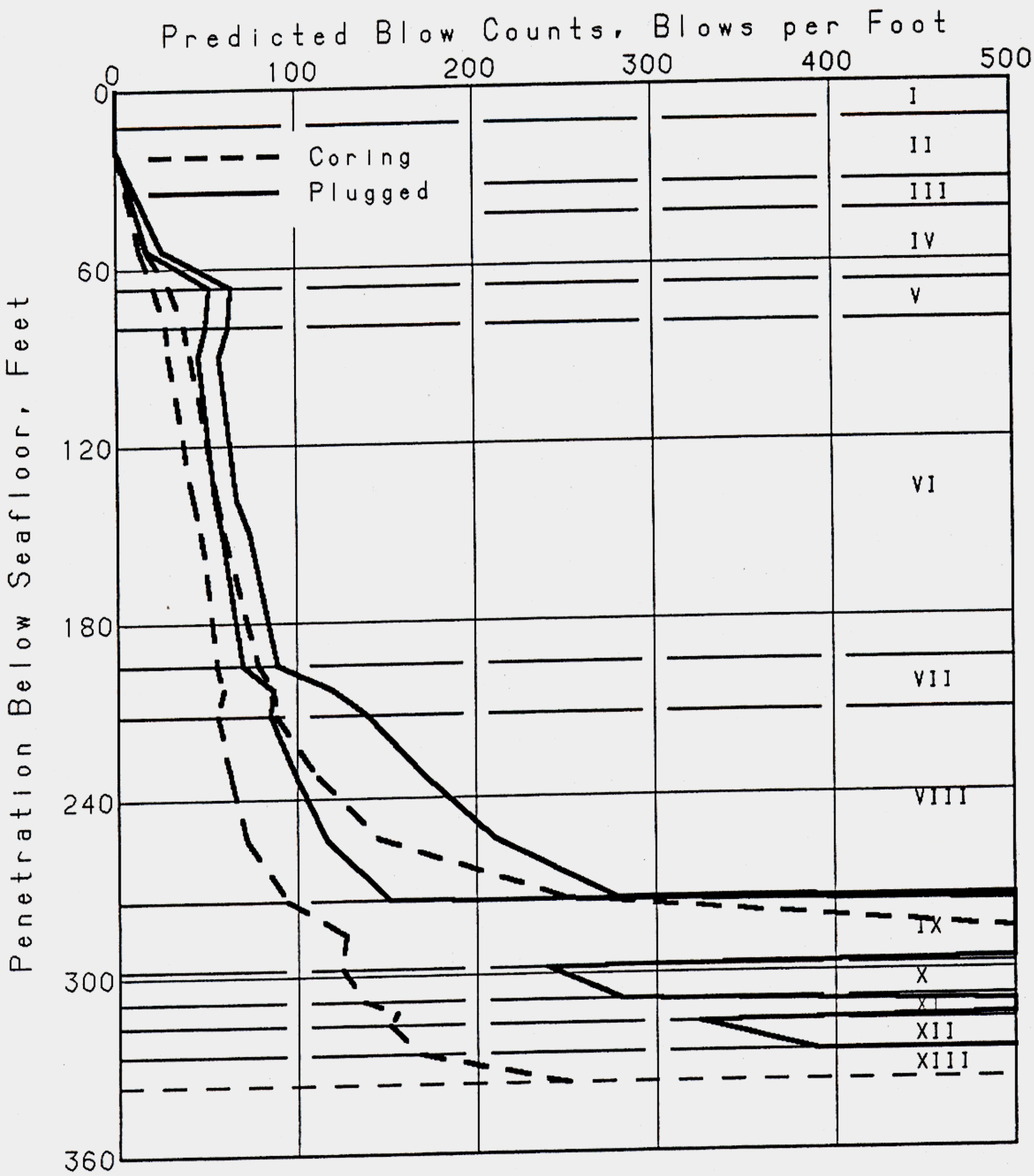
Drawn By: RP

Date: 5/11/98
Date:

Checked By: DR
Approved By:



PREDICTED BLOW COUNTS
Phase I, 60-in.-Diameter Pipe Piles
Conmaco 5700 Hammer
Boring 98-10
SFOBB East Span Replacement Project



PREDICTED BLOW COUNTS
Phase I, 60-in.-Diameter Pipe Piles
IHC S-250 Hammer
Boring 98-10
SFOBB East Span Replacement Project

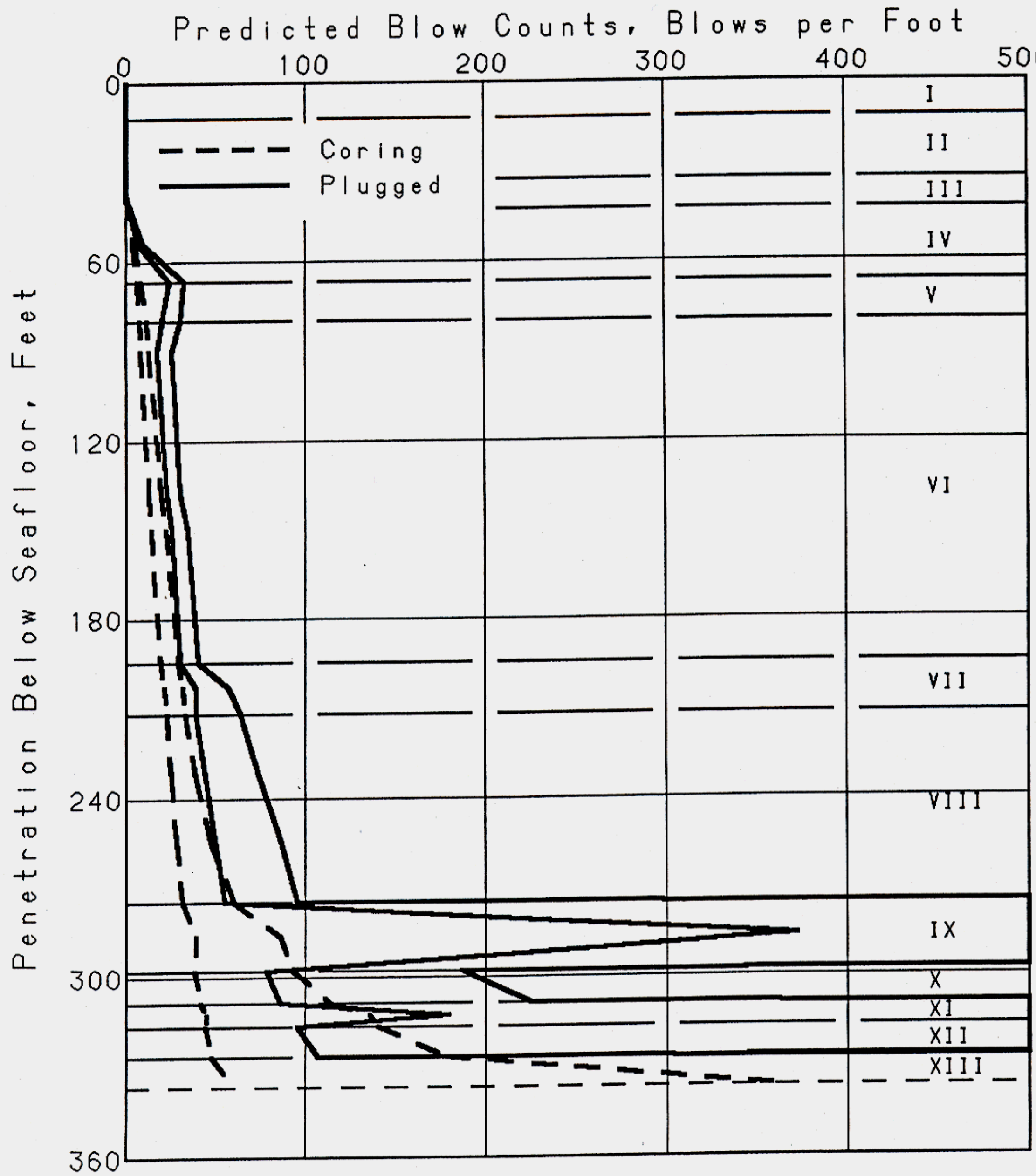
Checked By: D/r Date: 5/11/98
Approved By: Date:

Date: 4/24/98

Drawn By: RF

Date:
Date:

Checked By:
Approved By:



PREDICTED BLOW COUNTS
Phase I, 96-in.-Diameter Pipe Piles
Menck MRBS 5000 Hammer
Boring 98-10
SFOBB East Span Replacement Project

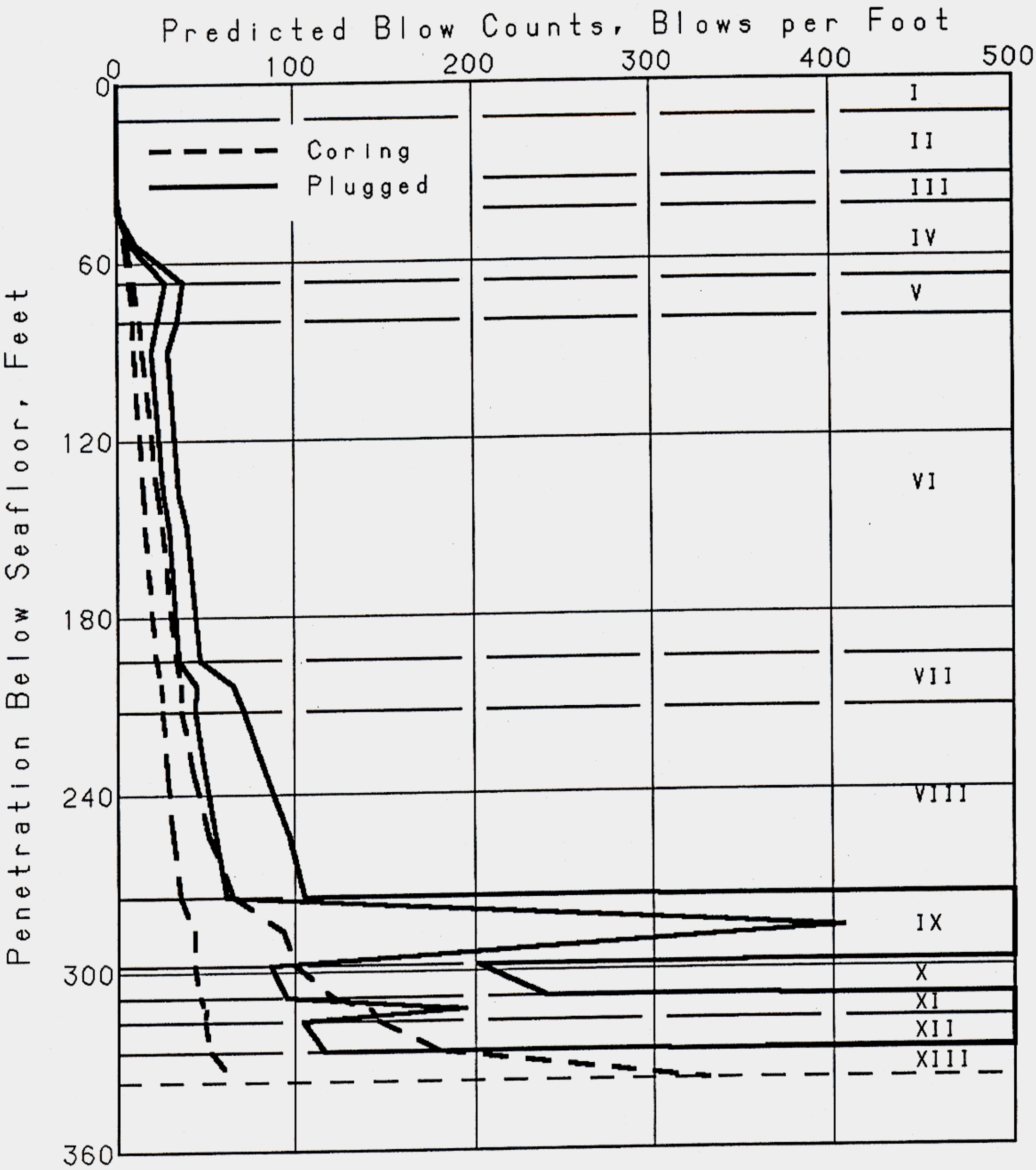
FUGRO

Date: 4/24/98

Drawn By: RFJ

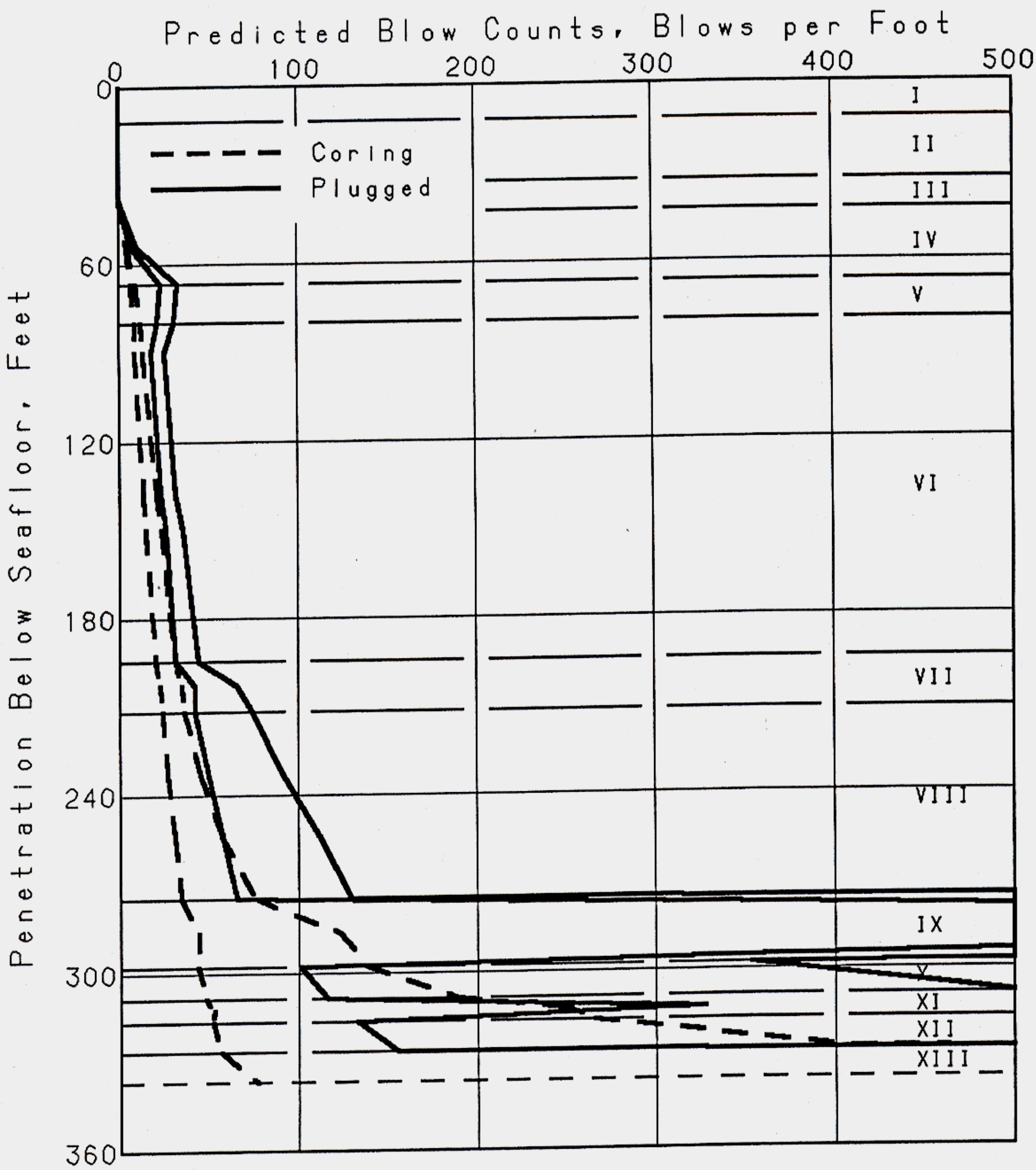
Date:
Date:

Checked By:
Approved By:

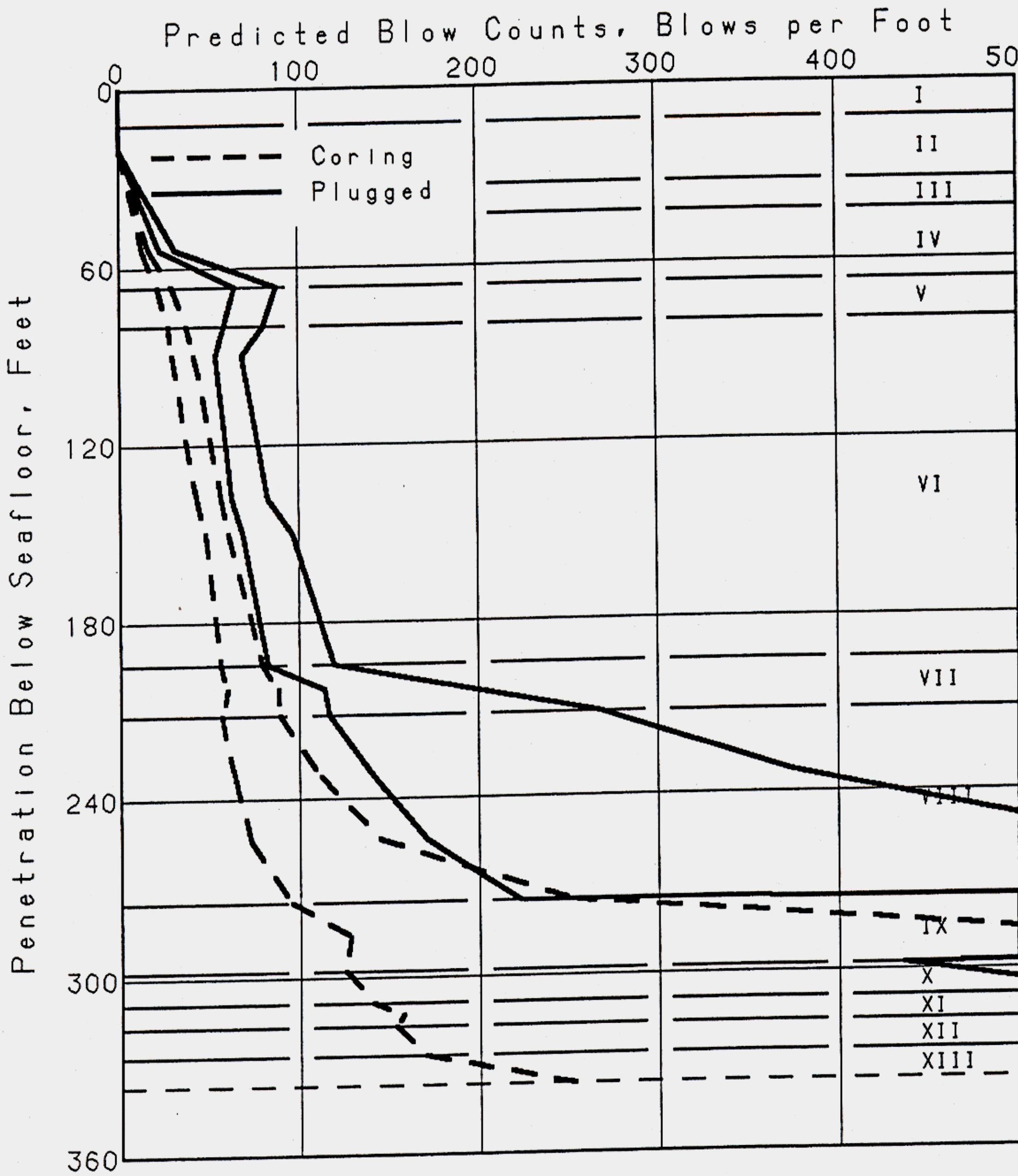


PREDICTED BLOW COUNTS
Phase I, 96-in.-Diameter Pipe Piles
Vulcan 5100 Hammer
Boring 98-10
SFOBB East Span Replacement Project

Date: 4/24/10
Drawn By: RFJ
Date:
Date:
Checked By:
Approved By:



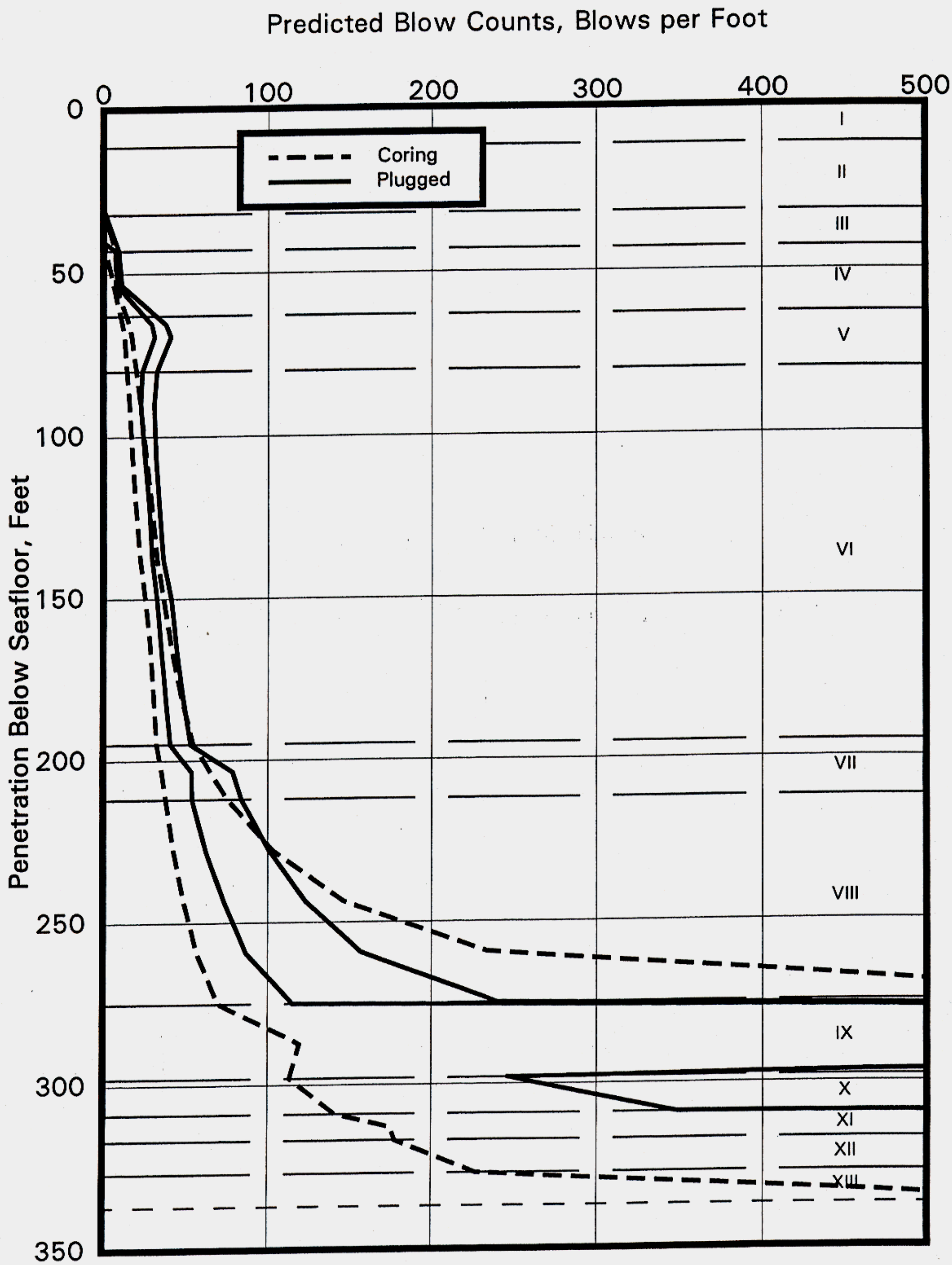
PREDICTED BLOW COUNTS
Phase I, 96-in.-Diameter Pipe Piles
Conmaco 6850 Hammer
Boring 98-10
SFOBB East Span Replacement Project



PREDICTED BLOW COUNTS
Phase I, 96-in.-Diameter Pipe Piles
IHC S-400 Hammer
Boring 98-10
SFOBB East Span Replacement Project

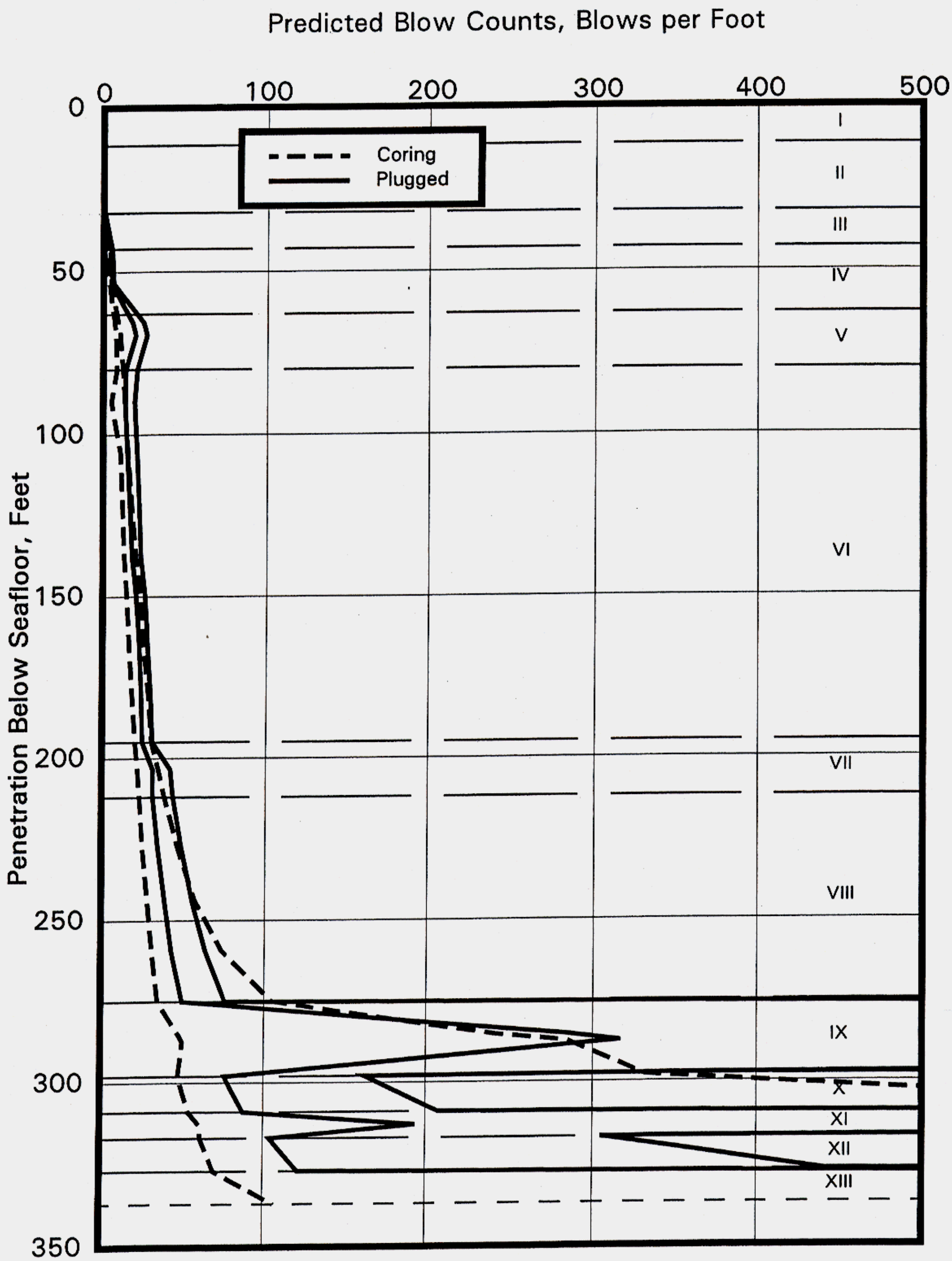
Drawn By: ___ Date: ___
Checked By: ___ Date: ___
Approved By: ___ Date: ___

PLATE 16



PILE DRIVING RECORDS
Phase II, 42-in.-Diameter Pipe Piles
IHC S-250 Hammer
Boring 98-10
SFOBB East Span Replacment Project

Drawn By: DK Date: 5/11/98
Checked By: Date:
Approved By: Date:



Drawn By: DM Date: 5/11/98

Checked By: Date:

Approved By: Date:

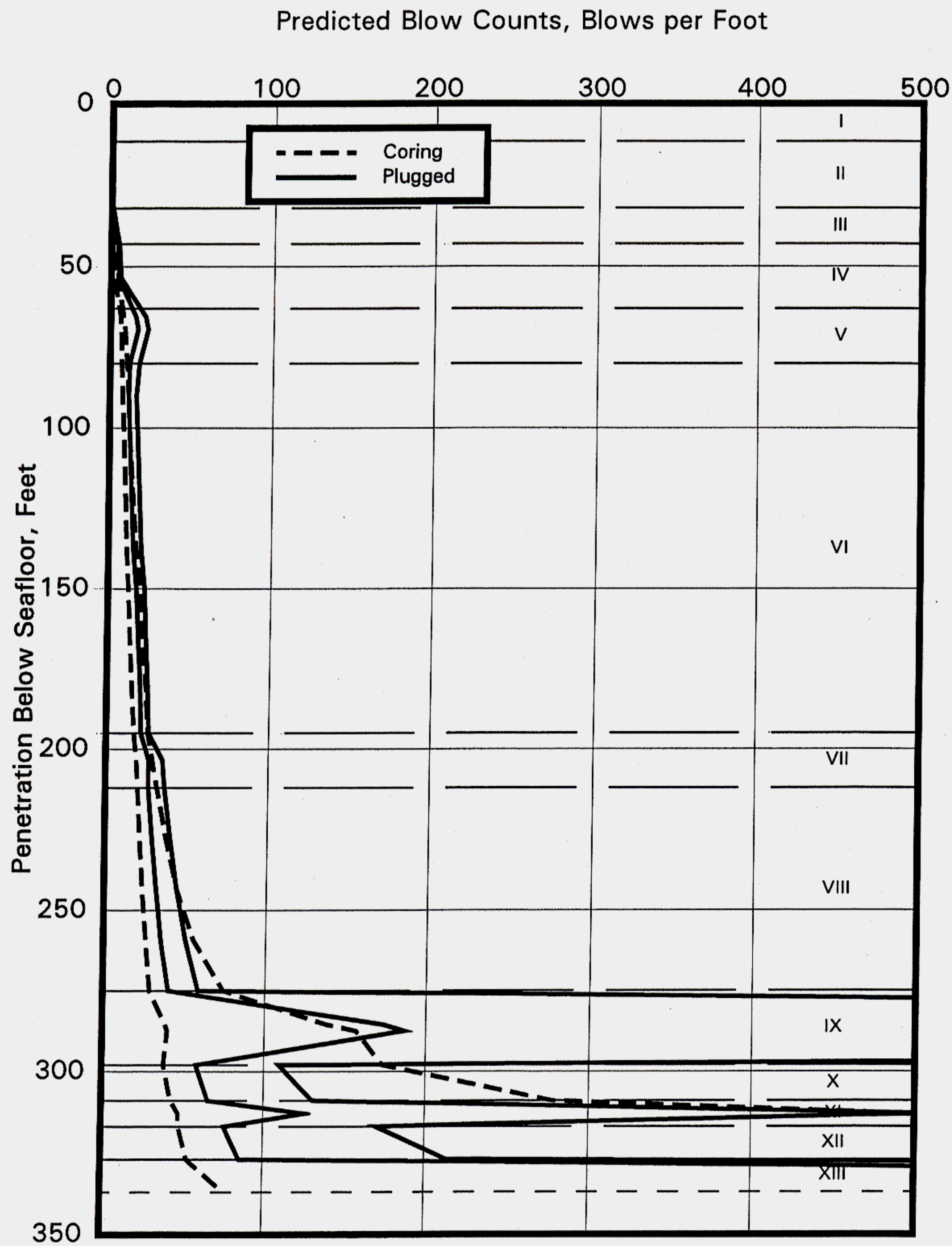
PILE DRIVING RECORDS

Phase II, 42-in.-Diameter Pipe Piles

IHC S-400 Hammer

Boring 98-10

SFOBB East Span Replacment Project



PILE DRIVING RECORDS
Phase II, 42-in.-Diameter Pipe Piles
IHC S-500 Hammer
Boring 98-10
SFOBB East Span Replacment Project

Drawn By: DM Date: 5/11/98
Checked By: Date:
Approved By: Date:

Drawn By: Date: 5/11/98
Checked By: Date:
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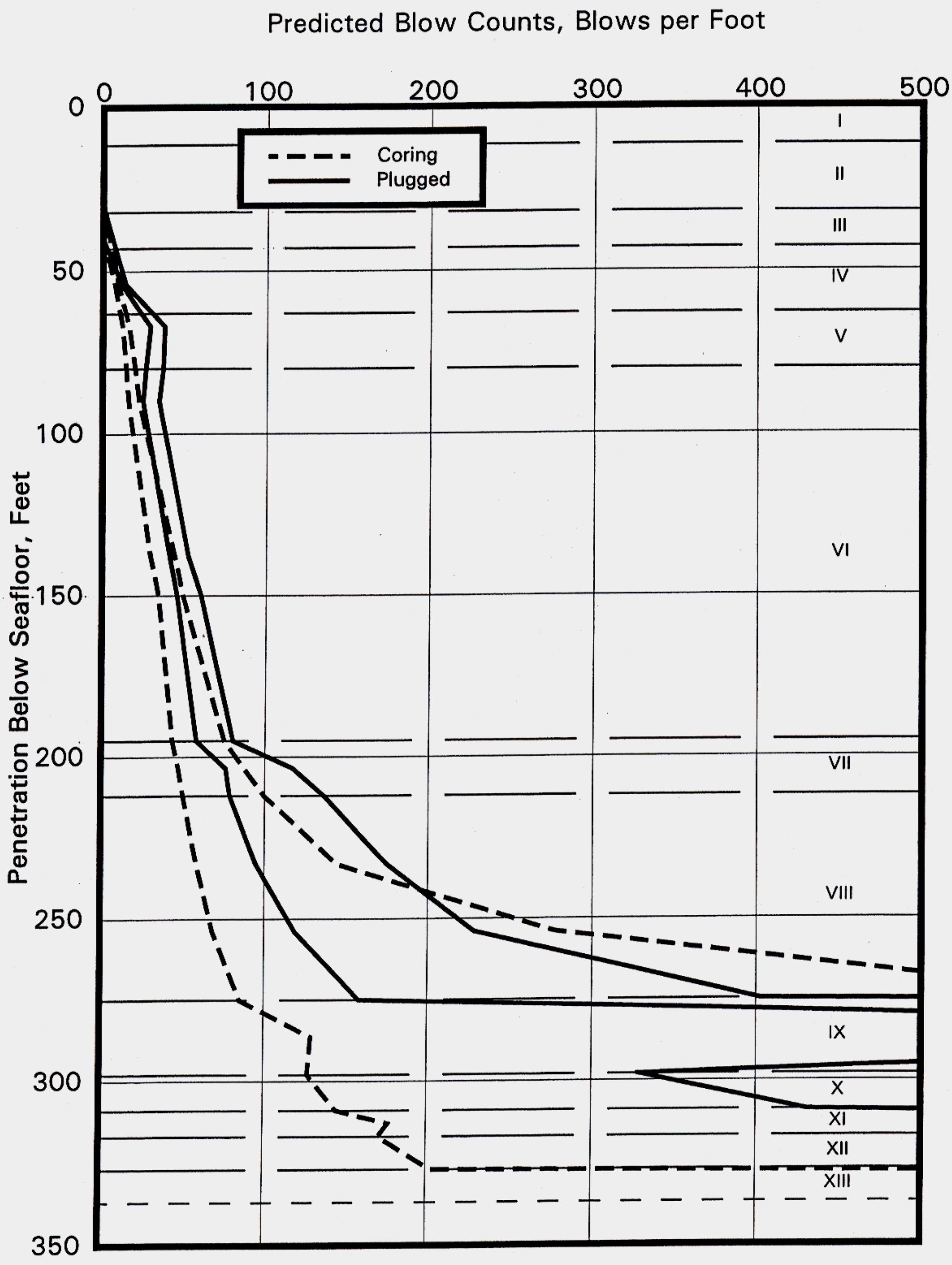
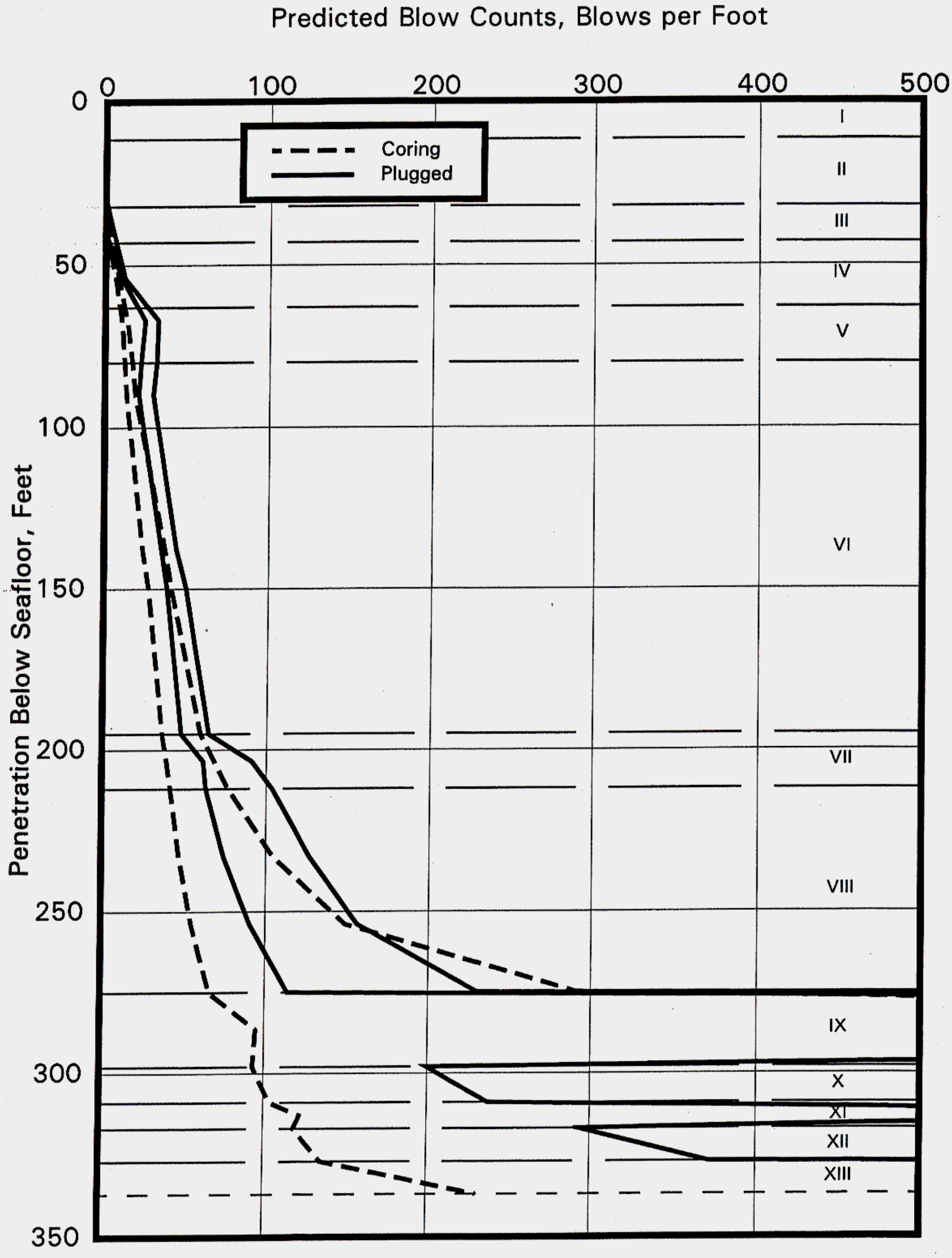


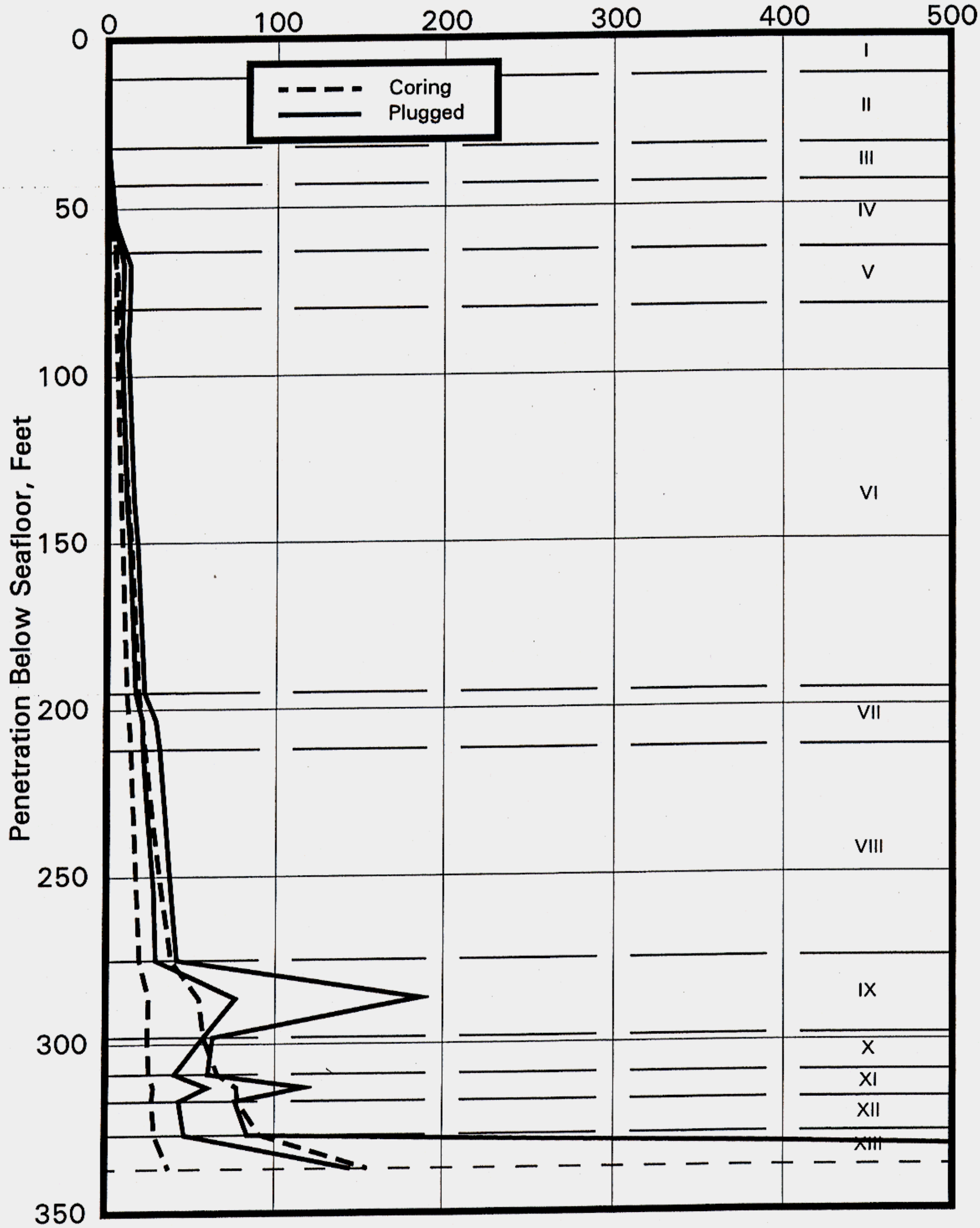
PILE DRIVING RECORDS
Phase II, 60-in.-Diameter Pipe Piles
IHC S-400 Hammer
Boring 98-10
SFOBB East Span Replacment Project



PILE DRIVING RECORDS
Phase II, 60-in.-Diameter Pipe Piles
IHC S-500 Hammer
Boring 98-10
SFOBB East Span Replacment Project

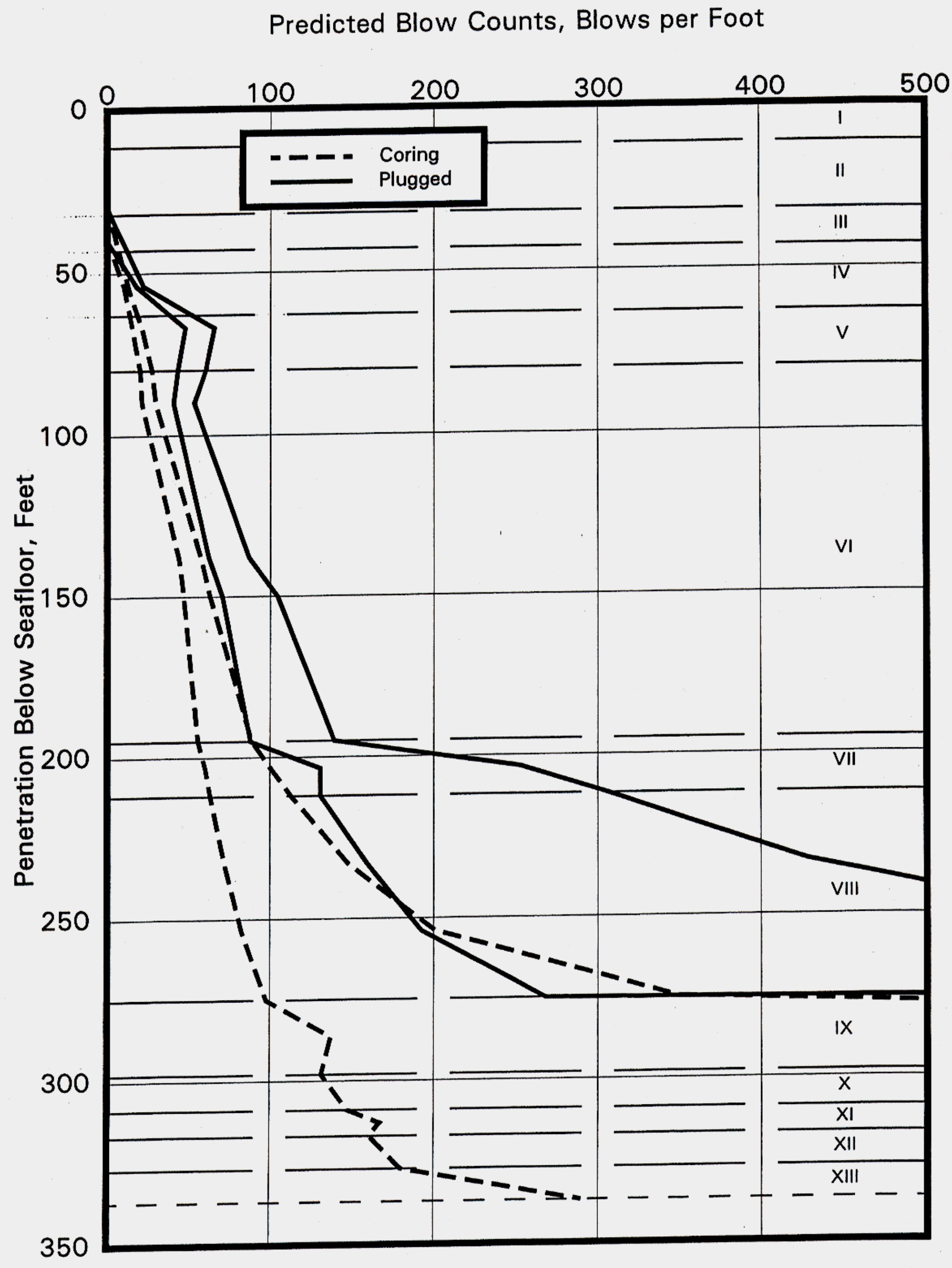
Date: 5/11/98
Drawn By:
Date:
Date:
Checked By:
Approved By:

Predicted Blow Counts, Blows per Foot



PILE DRIVING RECORDS
Phase II, 60-in.-Diameter Pipe Piles
Menck MHU-1000 Hammer
Boring 98-10
SFOBB East Span Replacment Project

Date: 5/11/98
Drawn By: DR
Checked By: Date:
Approved By: Date:



Drawn By: DM Date: 5/11/98

Checked By: Date:

Approved By: Date:

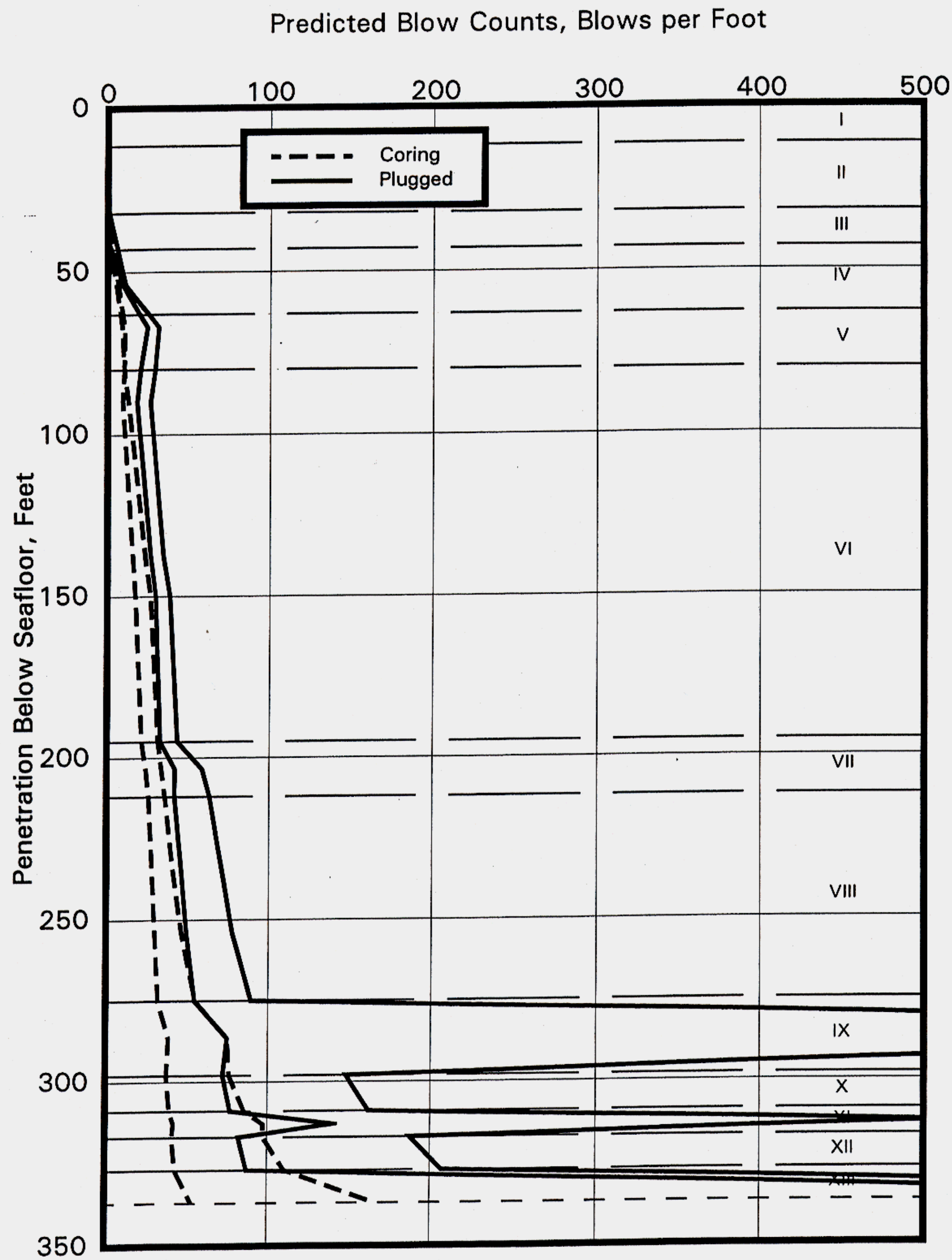
PILE DRIVING RECORDS

Phase II, 96-in.-Diameter Pipe Piles

IHC S-500 Hammer

Boring 98-10

SFOBB East Span Replacment Project



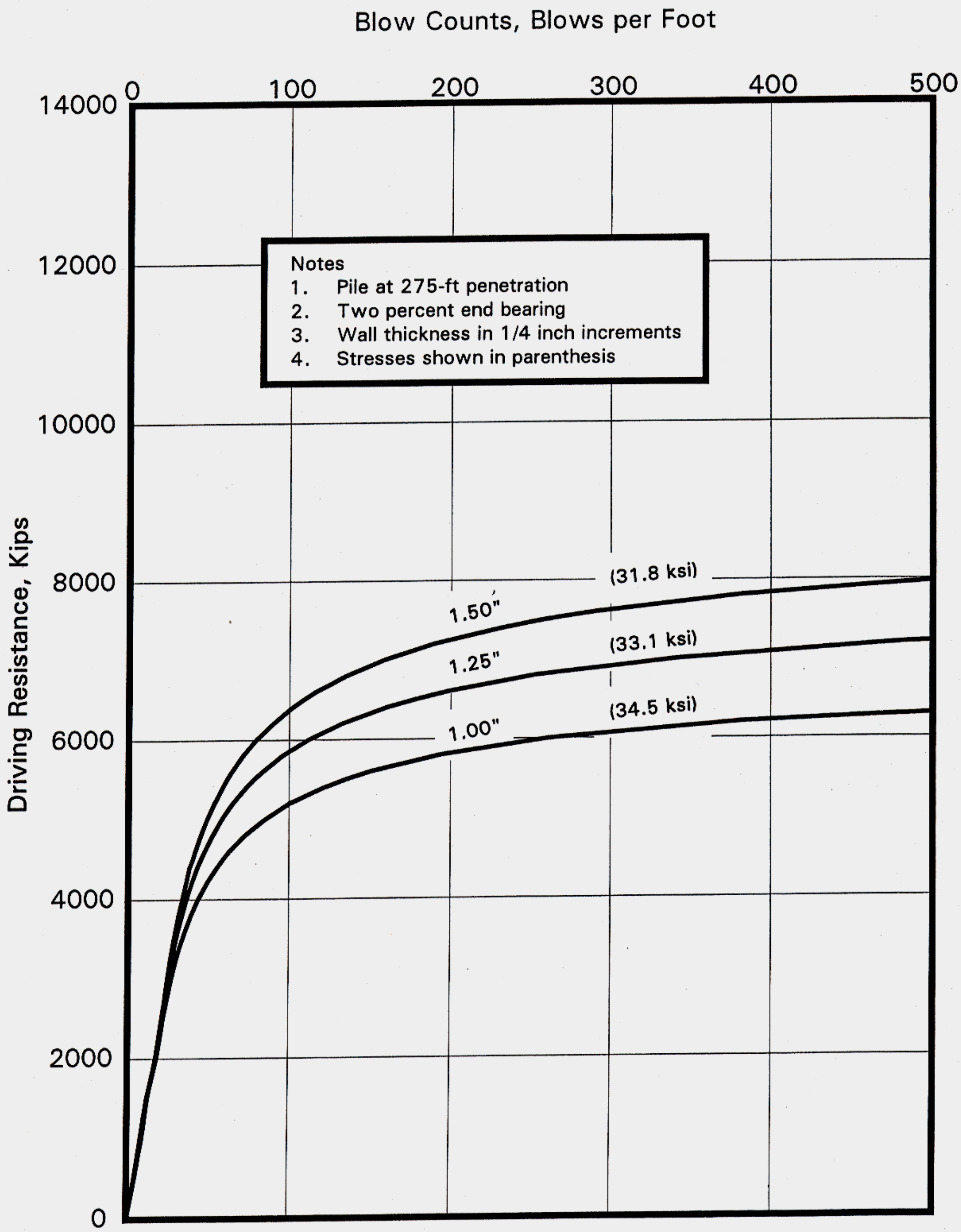
PILE DRIVING RECORDS
Phase II, 96-in.-Diameter Pipe Piles
MENCK MHU1000 Hammer
Boring 98-10
SFOBB East Span Replacment Project

Drawn By: DN Date: 5/11/98
Checked By: Date:
Approved By: Date:

Drawn By: DM Date: 5/11/98

Checked By: Date:

Approved By: Date:



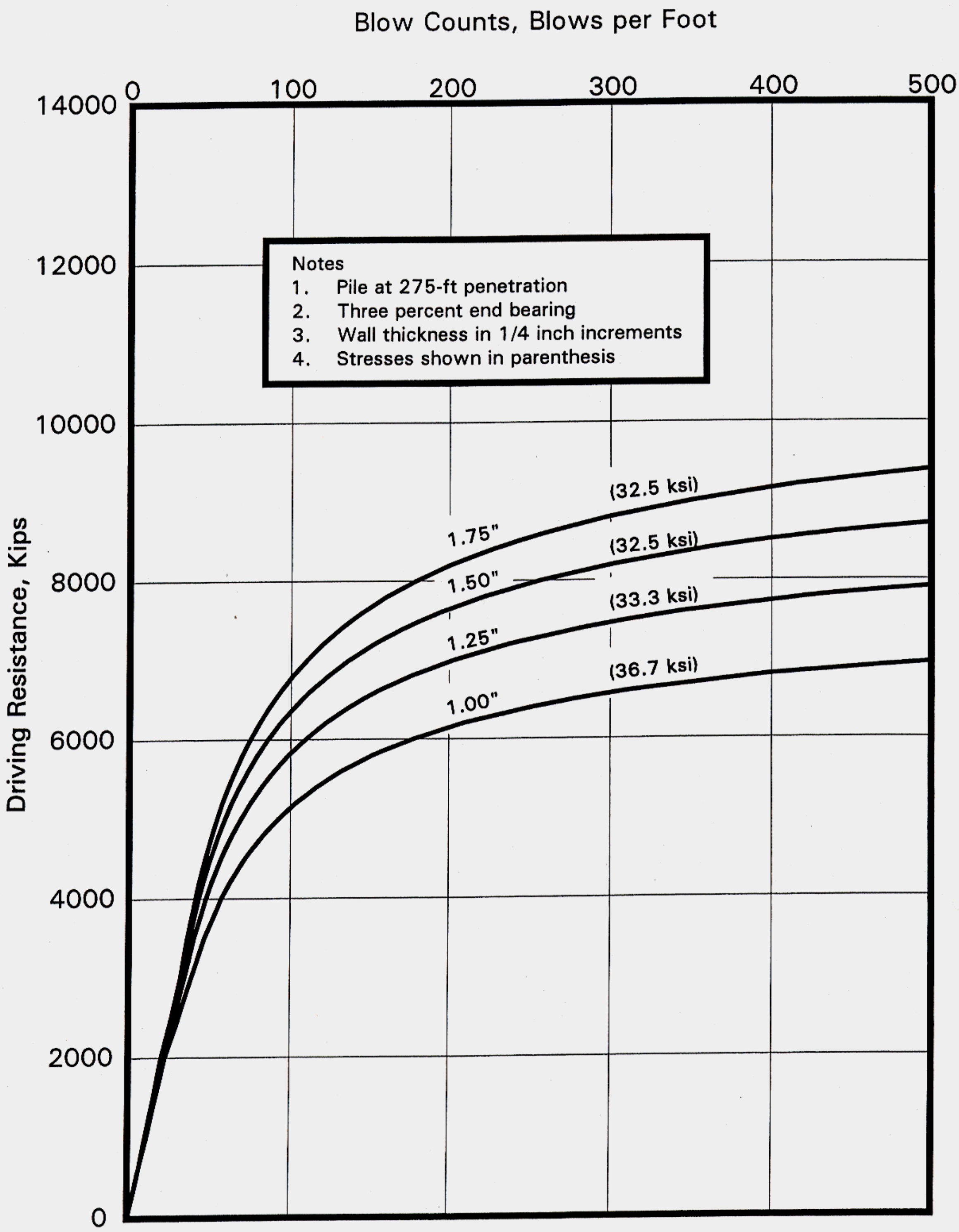
DRIVING RESISTANCE - BLOW COUNT CURVES

Phase II, 42-in.-Diameter Pipe Piles

IHC S-400 Hammer

Boring 98-10

SFOBB East Span Replacment Project



DRIVING RESISTANCE - BLOW COUNT CURVES

Phase II, 60-in.-Diameter Pipe Piles

IHC S-500 Hammer

Boring 98-10

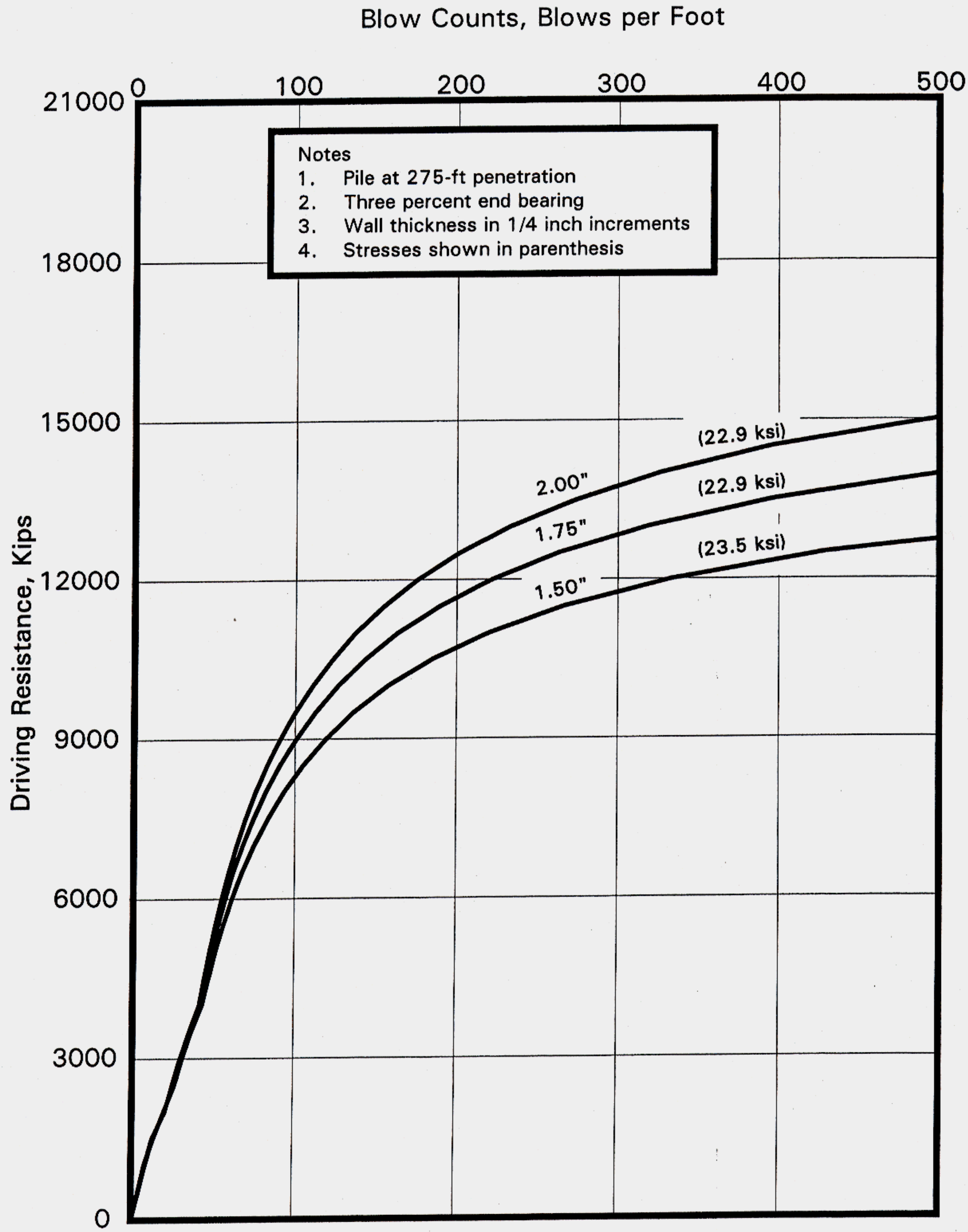
SFOBB East Span Replacment Project

Drawn By: D.4 Date: 5/11/98

Checked By: Date:

Approved By: Date:

Drawn By: DJL Date: 5/11/98



Checked By: Date:
Approved By: Date:

DRIVING RESISTANCE - BLOW COUNT CURVES
Phase II, 96-in.-Diameter Pipe Piles
IHC S-500 Hammer
Boring 98-10
SFOBB East Span Replacment Project

LARGE OFFSHORE HAMMER INVENTORY AND LIST OF HAMMER MANUFACTURERS

LARGE OFFSHORE HAMMER INVENTORY, PID PROJECT
SFOBB EAST SPAN SEISMIC SAFETY PROJECT

Date Generated: 3/30/99 ***Subject to Change Without Notice***

Make	Model	Max. Rated Energy		Who Has?	No. of Hammers	Comments
		K-ft	kJ			
Hydraulic Type						
Menck	MHU-3000	2213	3000	Heerema	1	
Menck	MHU-3000	2213	3000	Saipem	1	
IHC	S-2300	1896	2300	Heerema	1	
Menck	MHU-2100	1549	2100	Heerema	1	
Menck	MHU-2100	1549	2100	Saipem	1	
Menck	MHU-1700	1254	1700	Hyundai	1	
Menck	MHU-1700	1254	1700	Heerema	4	
Menck	MHU-1700	1254	1700	Saipem	3	
Menck	MHU-1700	1254	1700	McDermott	2	
IHC	S-1600	1180	1600	Seaway Heavy Lifting	1	
Menck	MHU-1000	738	1000	Saipem	2	
Menck	MHU-700	517	700	Menck	2	
Menck	MHU-500T	369	500	Menck	3	
Menck	MHU-500T	369	500	McDermott	2	
IHC	S-500	369	500	CNOCC	1	
IHC	S-500	369	500	ETPM	1	
IHC	S-500	369	500	Maersk	1	
IHC	S-500	369	500	Seaway Heavy Lifting	1	
IHC	S-500	369	500	Vulcan/MK	1	San Mateo Bridge
Steam Type						
Vulcan	5150	750	1016	McDermott	2	
Vulcan	5150	750	1016	In Singapore	2	
Vulcan	5150	750	1016	In Dubai	1	
Conmaco	6850	510	691	McDermott	2	
Conmaco	6850	510	691	"European Contractors"	4	
Vulcan	5100	500	677	McDermott	2	
Vulcan	5100	500	677	Global	2	
Vulcan	5100	500	677	"Overseas"	3	
Vulcan	5100	500	677	"Inactive"	3	
Conmaco	5700	350	474	McDermott	2	
Conmaco	5700	350	474	"European Contractors"	4	
Diesel Type						
Delmag	D-200-42	500	677	Delmag Houston	1	Delmag D-200-42 is brand new; not yet used

NOTE: IHC S-800 and S-1000 have not yet been built.

LIST OF LARGE OFFSHORE HAMMER MANUFACTURERS

Conmaco, Inc.
1602 Engineers Road
Belle Chasse, LA 70037
(504) 394-7330
Attn: Michael G. Favaloro

IHC Hydrohammer BV
P.O. Box 26
2960 AA Kinderdijk
6 Smitweg, Holland
011-31-7869-10301
Attn: Geert Jonker

or

Petro-Drive, Inc.
P.O. Box 53526
Lafayette, LA 70505-3526
(318) 837-1181
Attn: Ed Hebert

Menck GMBH
P.O. Box 1165
Werner von Siemens Strasse
D-2086 Ellerau, Germany
011-49-4106-700235
Attn: Ewald Moer

or

Pilemac
91 Greenville Road
Livermore, CA 94550
(800) 745-3622
Attn: George Smith

Vulcan Iron Works, Inc.
2909 Riverside Drive
P.O. Box 5402
Chattanooga, TN 37406
(423) 698-1581
Attn: Don C. Warrington